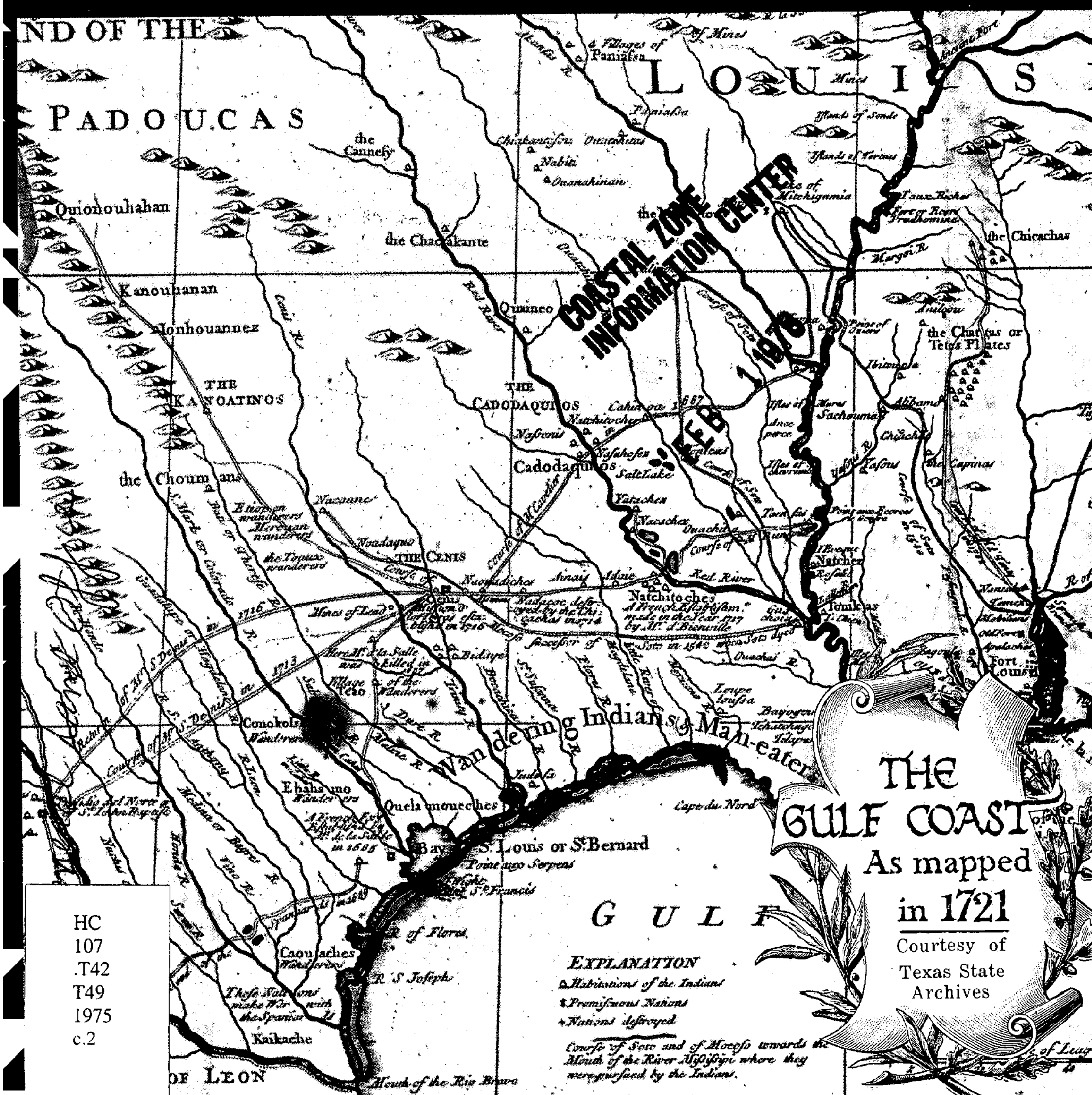
RESOURCES OF THE TEXAS COASTAL REGION



THE GULF COAST As mapped in 1721

Courtesy of Texas State Archives

RESOURCES OF THE TEXAS COASTAL REGION

THE COASTAL MANAGEMENT PROGRAM

General Land Office of Texas

Bob Armstrong, Commissioner

Ron Jones, Director

Charles M. Woodruff, Jr., Project Supervisor

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The contents of this report have been reviewed by the Texas Coastal Management Program Advisory Committee, and the program staff have considered their comments. However, the report does not necessarily reflect their views, and the staff of the Coastal Management Program assumes all responsibility for the contents of the report.

TABLE OF CONTENTS

A suite of 22 maps accompanies this report.

PREFACE

The Texas Coastal Management Program was initiated in June, 1974, as a joint undertaking by all the state's natural resource agencies. Leading this program at Governor Briscoe's request, the General Land Office has secured assistance under the federal Coastal Zone Management Act of 1972.

The federal coastal act is not mandatory, nor does it overshadow or significantly restrict the state's activities. With only two restrictions, it offers an important political incentive; that is, federal law will require all federal activities or assistance affecting the Texas coast to conform to the program developed by Texas. The two limits are that federal air and water quality standards cannot be changed by the program, and that national interests, such as defense, must be taken into account as the coastal program is developed.

The objectives of the Coastal Management Program are, through interagency cooperation and extensive public participation, to develop and recommend to the Legislature:

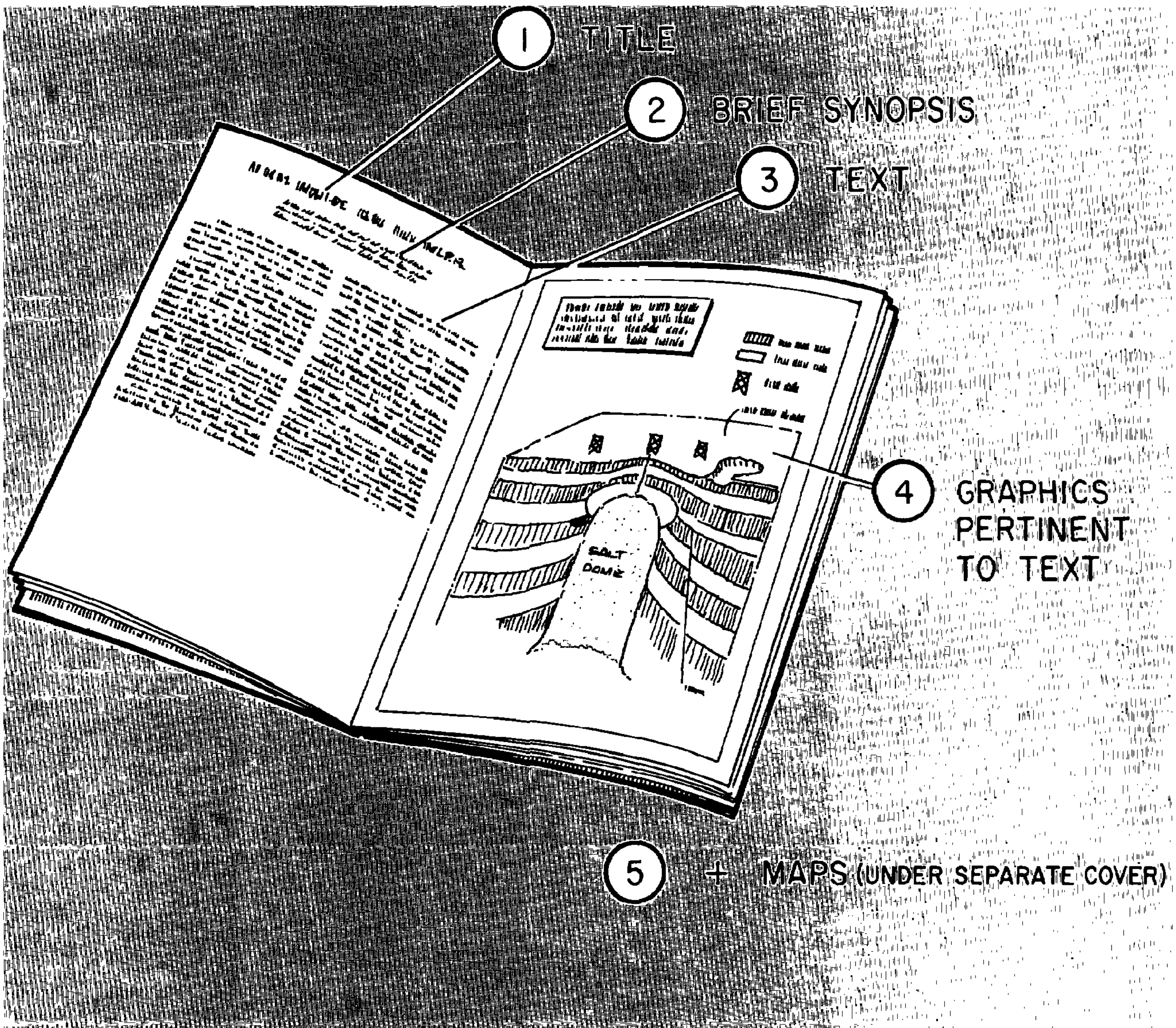
1. an improved and flexible policy-planning process which will ensure a continuing balance among future social, economic, and environmental needs along the coast and
2. the steps for implementing such a process.

In order to develop these recommendations, the program must review the coastal resources of the state and identify the demands which make these resources important. This information must, in turn, be presented to the public for full discussion and choice.

In this report, *Resources of the Texas Coastal Region*, the Texas Coastal Management Program attempts to answer questions about the natural resources of the Texas Gulf Coast. The report presents a general inventory of major resources and natural processes. It is intended only as an introductory document prefatory to an analysis of coastal problems and their component elements. This report does not attempt to present an exhaustive technical discourse on all important coastal resources, because detailed studies in such diverse disciplines as geology, biology, hydrology, and soil science could fill volumes. The purpose of this report is to give an overview of coastal resources in a concise textual manner.

The format used herein is designed to maximize the visibility of important points. The report is divided into 20 thematic sections, each of which covers a two-page spread (fig. 1). The left-hand page contains a title denoting the subject matter of the section followed by a headline summarizing the contents. The body of the text occupies the rest of the page. The right-hand page presents graphic material illustrating salient points discussed in the text. Eleven sections are further augmented by map displays accompanying the report. The maps depict the geographical relations among various types of coastal resources. Most of the displays also cite references for additional data concerning the respective resource subjects.

By reading the section headlines and viewing the accompanying graphics, a reader may grasp the main points of the report. However, the report has been designed as a unit, with text, graphics, and maps that are complementary in describing the many facets of resources in the Texas coastal region.



EXPLANATION OF REPORT FORMAT

INTRODUCTION

An understanding of the natural resource base and its complexity is a first step in the prudent use of lands and waters.

The resources of the Texas coastal region are many and varied. They include natural resources such as minerals, rivers, bays, tidal marshlands, scenic beaches, forests, abundant wildlife and fish, expanses of open space, and fertile soils. They include cultural resources such as industrial complexes, populous urban centers, highly productive agricultural lands, ranches, transportation corridors on land and water, recreational facilities, and a treasure trove of historical and archaeological sites. These resources, both natural and man-made, interact in many ways. No resource exists apart unto itself.

Natural systems affect each other in complex ways (fig. 2). For example, upland game depends on vegetative cover that depends on soil conditions that depend, in turn, on local bedrock, climate, and the lay of the land. Climate is a function of the lay of the land which, in turn, is dependent on the geologic setting, vegetation, and (to come full circle) climate. The amount of water in a river is dependent on river basin size, climate over the whole basin, and bedrock conditions all along the river course.

Natural systems affect man (fig. 3). The courses of rivers and the locations of natural channels into bays have commonly influenced the locations of early settlements, many of which have grown into modern cities. Cataclysmic processes such as storms and floods have acted to curtail local human expansion. Soil conditions and the availability of water have determined the locations of agricultural lands. The presence of mineral resources has generally predetermined the location of great industrial complexes.

Human activities affect natural systems (fig. 4). Cities encroach upon prairies and diminish wildlife habitats. Ports and ship channels compete with fish and shellfish for the use of the bays. Resources are depleted by mineral extraction. Local balances are upset, and unforeseen natural processes are activated. For example, increased beach erosion may occur downcurrent from jetty construction, and ground subsidence commonly occurs as a result of large-scale groundwater pumping. On the other hand, equilibria also exist in many areas where natural and human systems coexist without apparent problems.

Finally, human activities affect other actual or potential human uses of the land and waters (fig. 5). A certain type of resource use may preclude others, although there are notable examples of concurrent multiple use. How lands and waters are used is largely determined by economic demands, and locally, by the vagaries of human preference. If land is more valuable for housing than for agriculture near rapidly expanding cities, then agricultural land will generally diminish there. Certain problems arise where the complete value of a resource is not accounted within the market system. An example might be the overuse or misuse of the atmosphere as a free waste-disposal medium without paying the cost of the effects on human health that result from breathing polluted air. Air is only one resource we use as if it were free, whereas actually a social cost results from its misuse.

In summary, the natural resource base—land, water, biota, and minerals—is finite. Problems result from human demands on these natural systems, because all land and waters are not equally suited for all uses. For example, homeowners may be unwittingly subjected to natural hazards because they are not aware of the hazardous processes. The public has a right to know whether their homes lie in a floodplain or along an active fault. The problem here is that of providing the necessary information. The planner and public policymaker must, in their respective spheres, understand the diversity of lands and waters in order to encourage sound and balanced development of multifaceted human systems. One of the responsibilities of public planners and policymakers should be the collection and dissemination of information regarding the complexity of natural resources. Heretofore, projects in both the public and private realms have too often been undertaken without an adequate knowledge of constraints imposed by local land and water conditions. To contribute to the dissemination of information on the location of natural resources and selected human resources is the purpose of this report. This information should aid in the prudent use of the lands and waters of the coast.

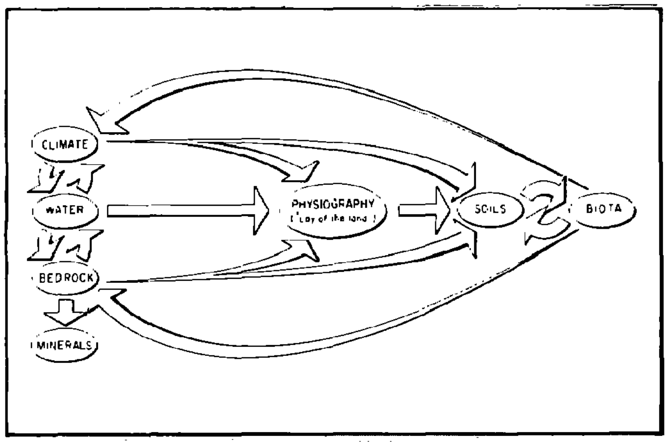


FIGURE 2

SCHEMATIC DIAGRAM OF INTERACTIONS AMONG SELECTED NATURAL RESOURCE SYSTEMS.

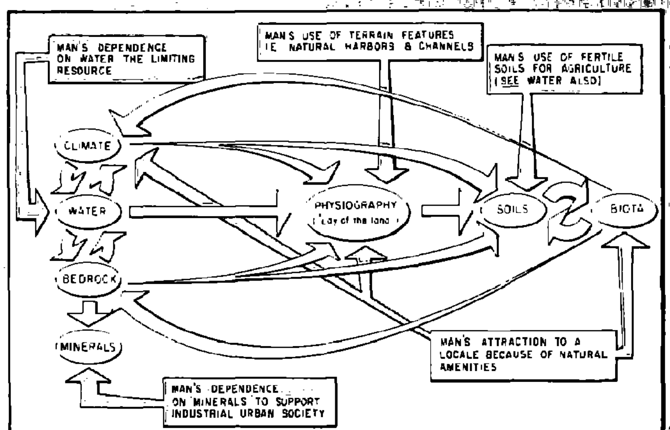


FIGURE 3

SCHEMATIC DIAGRAM SHOWING INTERACTIONS OF SELECTED NATURAL RESOURCE SYSTEMS ON MAN.

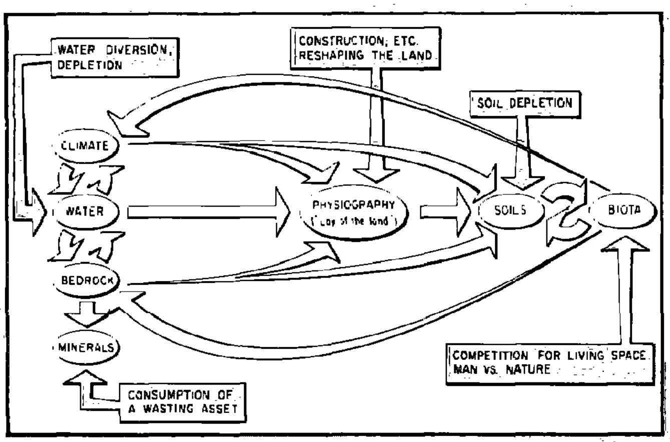


FIGURE 4

SCHEMATIC DIAGRAM SHOWING MAN'S INTERACTIONS WITH SELECTED NATURAL RESOURCE SYSTEMS.

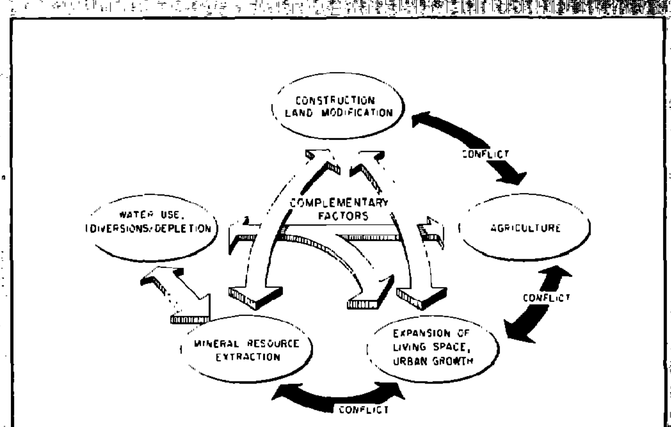


FIGURE 5

SCHEMATIC DIAGRAM SHOWING INTERACTIONS OF SELECTED HUMAN ACTIVITIES WITH OTHER HUMAN ACTIVITIES.

AREA INCLUDED IN STUDY

A tentative coastal region is established that includes 27 counties. The Texas Coastal Management Program will focus its attention on these counties in order to properly define a subarea in which the state has the need for management.

At the inception of the Texas Coastal Management Program, 27 counties were designated as part of the tentative coastal region.* The counties included are: Aransas, Bee, Brazoria, Calhoun, Cameron, Chambers, Fort Bend, Galveston, Goliad, Hardin, Harris, Hidalgo, Jackson, Jefferson, Kenedy, Kleberg, Liberty, Matagorda, Montgomery, Nueces, Orange, Refugio, San Patricio, Victoria, Waller, Wharton, and Willacy.

This larger coastal region encompasses approximately 27,000 square miles (fig. 6), including all submerged lands of the bays and offshore to the three-league limit of state-owned lands. The delimitation of this area as the tentative coastal region was based partly on political criteria and partly on natural or economic interactions within the region. County boundaries were chosen rather than natural boundaries (such as an elevation above sea level or river basin limits) because counties are easily recognized political units. This ensures that there will be no doubt as to the area initially included for consideration by the program. The designated counties include all bay and estuarine areas as well as those inland counties that are closely tied economically or politically to the areas directly adjacent to the bays or open ocean.

The larger (tentative) coastal region serves as an arena for presentation of interactions between natural and human systems. The areas ultimately recommended to be covered by an ongoing management program will probably be a small fraction of this larger region. For example, coastal waters constitute an area upon which attentions may be logically focused (fig. 6).

*For the sake of completeness, the companion coastal economic report includes two additional counties (Brooks and Jim Wells) for a total of 29.

TENTATIVE BOUNDARIES OF THE TEXAS COASTAL REGION

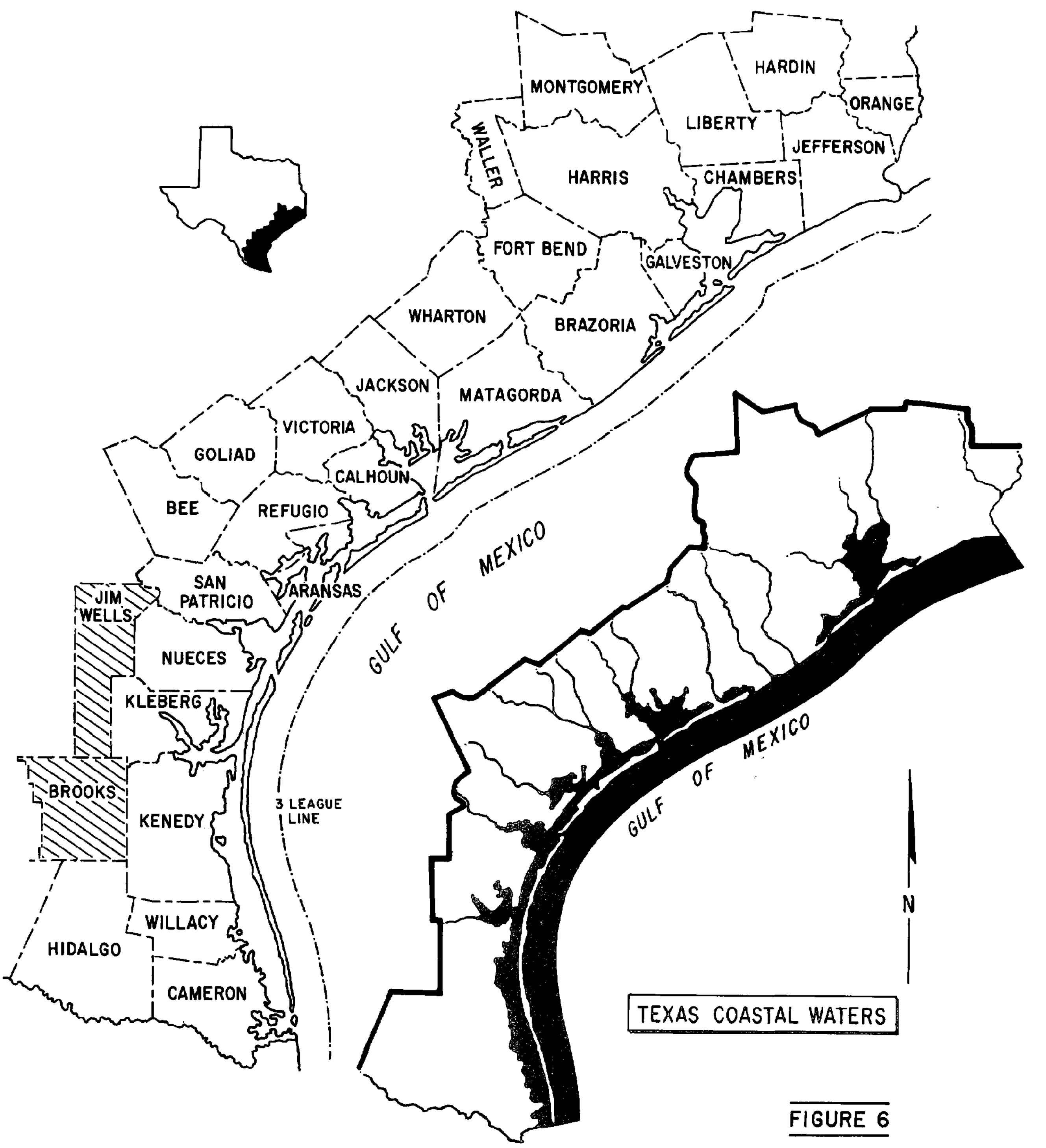


FIGURE 6

PREVIOUS WORK AND CURRENT OBJECTIVES

The presentation of a natural resource inventory by the Texas Coastal Management Program is based on a search of current data files. The program will result in map depictions showing geographic relations among various resources. It will also present selected references to current state or federal resource analysis programs.

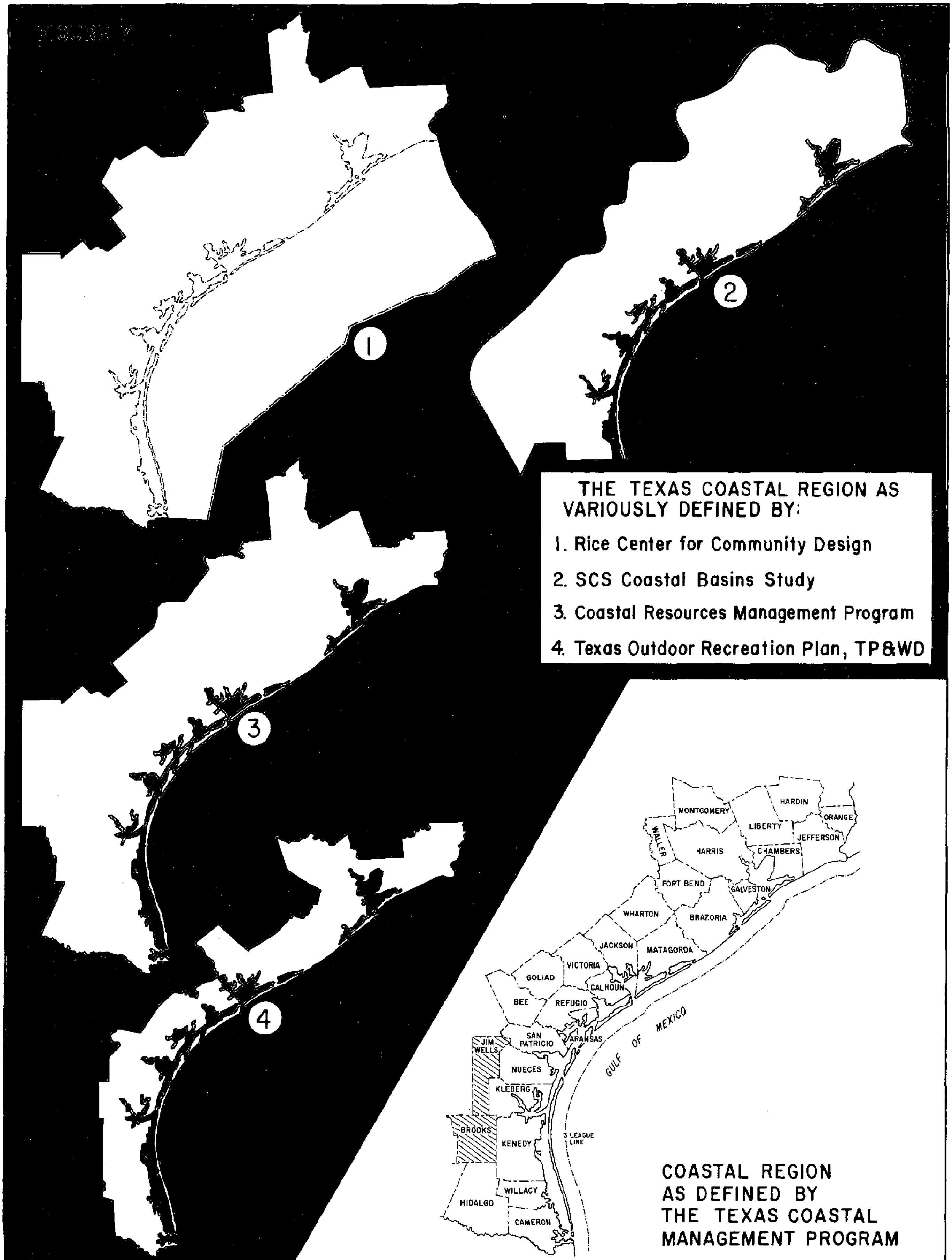
The collection of technical information necessary for enlightened planning is an ongoing process. Researchers in state and federal agencies, universities, corporations, and private individuals have collected a wealth of information on resources in the coastal region. New data are constantly being added to the basic reservoir of knowledge, but the picture is always a tentative one. It depicts the coastal region, its natural resources, and its societal and economic interactions at one point in time. The picture changes for two reasons. First, more complete knowledge changes one's perception of an area, and the acquisition of knowledge is a continuing process. Second, the coastal region is a composite of dynamic systems—complex areas that change from day to day and year to year. Likewise, human demands on (or interactions with) resources change. Thus, studying such a dynamic area is like shooting at a moving target—only more difficult. Researchers dealing with coastal systems can only approximate the real world. They can never make the systems stand still. They can never gain complete and final knowledge.

Because of time constraints, the Texas Coastal Management Program has relied largely on existing information for the inventory of resources in the coastal region. The principal data reservoirs are those of the various state agencies. Texas is fortunate to have several detailed studies of coastal resources that predate the inception of this program. Many member agencies of the Interagency Council on Natural Resources and the Environment have contributed basic data to this natural resource inventory. They include the Bureau of Economic Geology at The University of Texas at Austin, the Texas Parks and Wildlife Department, the Texas Water Development Board, the Texas Water Quality Board, the Texas Historical Commission, and various research branches at Texas A&M University. Federal entities that have furnished data are the Soil Conservation Service (SCS), the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey, and the U.S. Army Corps of Engineers.

In addition to basic data collection that predated this program, there have been numerous projects concerning "planning for coastal management" with attendant inventories and summaries of resource data (fig. 7). Some of the planning ventures have been regional in scope, covering the entire Texas coast, whereas others have concentrated on a single county or on a council of governments (COG) area. The inventories associated with these planning endeavors have different objectives. For instance, some have concentrated primarily on water resources, soil and agricultural resources, or marine fisheries resources, while others have covered the entire range of coastal resources. Previous regional planning endeavors include the Coastal Resources Management Program, initiated by the 63rd Legislature under the sponsorship of the ICNRE; the Texas Water Plan prepared by the Texas Water Development Board; the Texas Coastal Basins Study by the SCS; the Texas Outdoor Recreation Plan by the Texas Parks and Wildlife Department; and the Texas Coastal Management Program of the Rice Center for Urban Design. The U.S. Bureau of Land Management conducted a supra-regional planning effort in its inventory of the resources affected by outer continental shelf petroleum development. Subregional studies for management purposes included the National Science Foundation-Research Applied to National Needs (NSF-RANN) study of the Corpus Christi area, carried out by a research team from The University of Texas; the NSF-RANN Program in Chambers County effected by the Southwest Center for Urban Research (SCUR) at Houston; river basin plans by the Texas Water Quality Board; watershed management plans by the SCS; water resource and water-related transportation plans by the U.S. Army Corps of Engineers; county highway plans; and planning studies done by various COGs, counties, and municipalities.

In short, the concept of planning and coastal management in Texas is well-travelled ground. Likewise, attempts at inventorying resources of the region have been made by various agencies and institutions. Thus, this program does not purport to present fundamentally different concepts, nor (at the outset at least) does the program purport to present new technical data. Still, there is a clear justification for yet another overview of coastal resources; namely, that despite all the extant information regarding coastal resources, there are still glaring data deficiencies. It is part of the purpose of the Texas Coastal Management Program to present a complete (if generalized) depiction of the current state of knowledge regarding coastal resources, giving due credit to the agencies, institutions, or persons who originally collected the data. Second, based on this depiction, judgments will be made on technical deficiencies in the information base that hamper enlightened decision-making regarding resource allocation. Third, the depiction should reveal the geographic and conceptual areas where overlap in information-gathering has occurred because of failures in communication and coordination among various groups.

Ultimately, management decisions can be made by the state only where the state has a clear mandate for management *and* where an information base adequate for management purposes exists. At this time certain areas owned by the state and critical to the state's interests may be inadvertently lost—not because of lack of willingness to manage, but because of a lack of information that clearly demonstrates the criticality of these areas.


THE TEXAS COASTAL REGION AS VARIOUSLY DEFINED BY:
1. Rice Center for Community Design
2. SCS Coastal Basins Study
3. Coastal Resources Management Program
4. Texas Outdoor Recreation Plan, TP&WD
1
2
3
4
MONTGOMERY
HARDIN
ORANGE
LIBERTY
WALLER
JEFFERSON
HARRIS
CHAMBERS
FORT BEND
GALVESTON
WHARTON
BRAZORIA
JACKSON
MATAGORDA
VICTORIA
GOLIAD
CALHOUN
BEE
REFUGIO
SAN PATRICIO
ARANSAS
JIM WELLS
NUECES
KLEBERG
BROOKS
KENEDY
WILLACY
HIDALGO
CAMERON
GULF OF MEXICO
3 LEAGUE LINE
COASTAL REGION AS DEFINED BY THE TEXAS COASTAL MANAGEMENT PROGRAM

INVENTORY FORMAT: MAPS

A suite of maps graphically depicts the location of coastal resources. These maps show landforms, substrate, water resources, physical processes, soils, biologic resources, potential mineral resources, historical-archaeological sites, and current land use. A synthesis of these maps shows an approximate boundary of coastal waters and composite natural resource areas within these waters. Another map depicts geographic areas of particular concern nominated by various state agencies.

A map is a scale model of a part of the earth's surface. Maps show areal relations among (and variations in) a number of subjects or themes. There are geologic maps, soil maps, topographic maps, hydrographic maps, maps showing the locations of oil fields or mineral leases, property maps, political boundary maps, and many other kinds of map displays.

How much information a map can impart is largely a function of map scale, the ratio of the size of the map to the total land area covered. Large-scale maps generally show more detail than those of small scale (fig. 8). The maps presented herein are at a regional (relatively small) scale of 1:500,000, which means that one unit of distance on the map equals 500,000 equal units on the ground. For instance, one inch on the map equals 500,000 inches on the ground, so that at our working scale, one inch on the map equals about 8 miles on the ground.

Using a set of maps for a regional inventory of the land, water, culture, and other resources has advantages and disadvantages. One advantage is the ease with which different resource systems may be viewed. Maps of the same area showing geology, soils, and vegetative assemblages are a graphic aid in understanding the interaction and interdependence among these natural entities. Likewise, resource conflicts can be readily envisioned by viewing maps showing the conflicting features. For example, maps depicting both cultural features and potentially active natural processes may reveal dangers, such as where cities lie in flood-prone areas.

A disadvantage of using maps in such a regional overview is the necessary oversimplification of complex natural systems because of scale and the inability to adequately depict dynamic systems. The point is that natural systems—whether they be biologic, geologic, or hydrologic—are extremely complex, and at a scale of one inch to 8 miles, much of the complexity is necessarily lost. To retrieve the picture of complex systems underlying this regional synthesis, one must refer to the basic data source from which the regional maps are derived. The citation of original data sources is an integral part of this regional presentation.

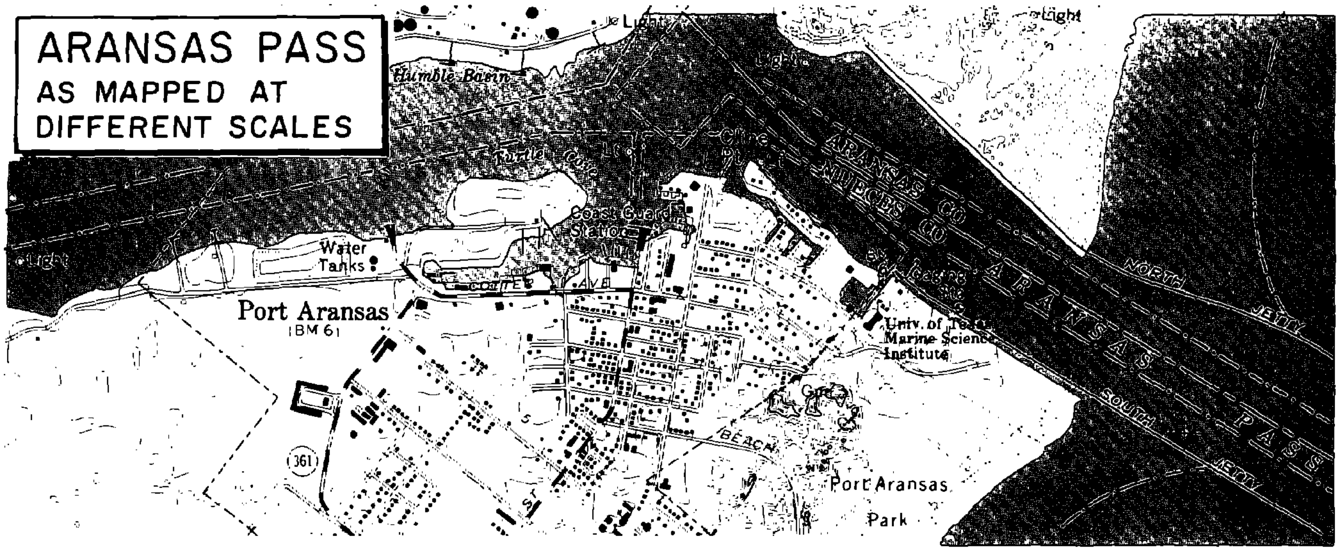
The inability of mappers to "capture" dynamic systems presents problems. Maps can present a picture at a point in time, but in a dynamic system—as the coastal region largely is—the static (map) picture sooner or later becomes outdated. Attempts to place static boundaries on eroding or accreting shorelines, expanding or waning marshes, or burgeoning cities, involve continuing battles against time and change. An extreme illustration of mapping dynamic boundaries is seen in the daily weather telecast where a satellite "map" of cloud formations is viewed and interpreted. The system changes minute by minute and yesterday's map will not show today's weather. In this instance, space technology has come to the rescue of the meteorologist, and a new map is constructed on a daily basis. Fortunately for our purposes, marsh changes and beach adjustments are not as abrupt as the vagaries of clouds and frontal systems. Still, problems exist, and data presented on maps are almost always obsolete to some degree at the outset.

To produce the enclosed maps, resource information was compiled at a scale of 1:250,000 on 7 sheets depicting the entire coastal region. This base was constructed especially for the Texas Coastal Management Program by the Bureau of Economic Geology at The University of Texas at Austin. The base maps show natural and cultural features, including bay and Gulf shorelines, stream courses, intracoastal waterways, and major highways and railroads. Names of major physical and cultural areas are also included. These maps have an approximate dateline of 1968.

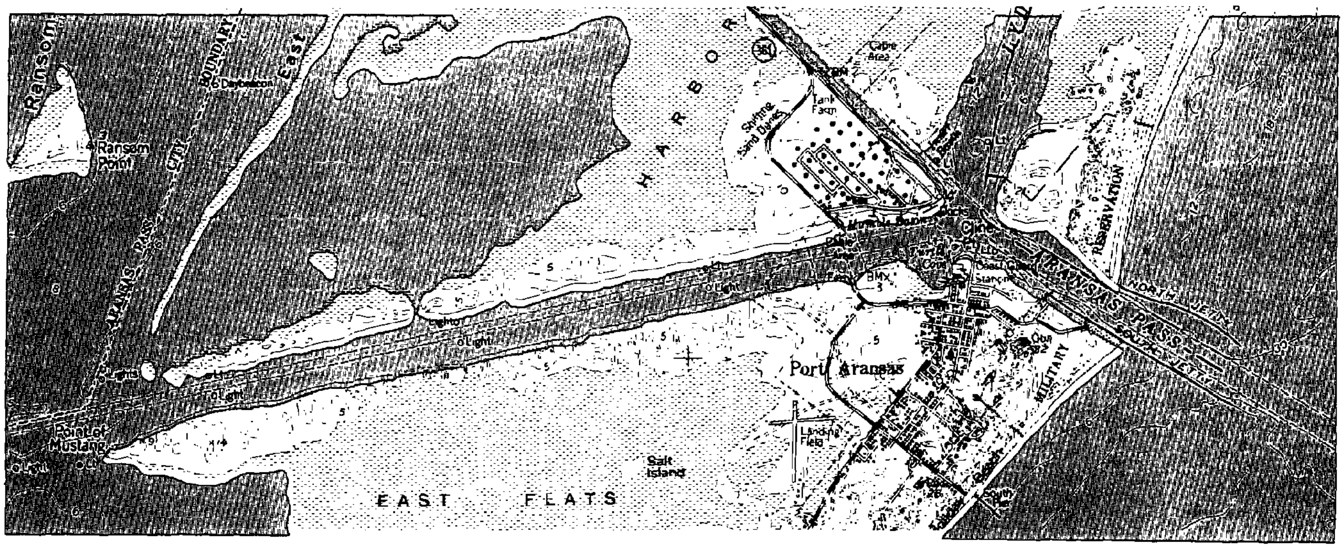
A variety of data were compiled from various sources onto the working base: topography and landforms, geologic substrate, potential mineral deposits, generalized soil capabilities, natural processes, water features, biota, current land use, and historical-archaeological sites. In addition, a map was constructed showing a composite of natural systems within coastal waters. Also, areas of particular concern nominated by state agencies were compiled onto a single map base.

The information compiled onto the scale of 1:250,000 was then transferred by skilled cartographers onto the final map base of 1:500,000. The 7 sheets composing the work base have been condensed onto a new base depicting the entire coastal region on 2 sheets. These sheets have been termed the "upper coastal region" and the "lower coastal region," with the dividing line being arbitrarily set in the vicinity of San Antonio Bay.

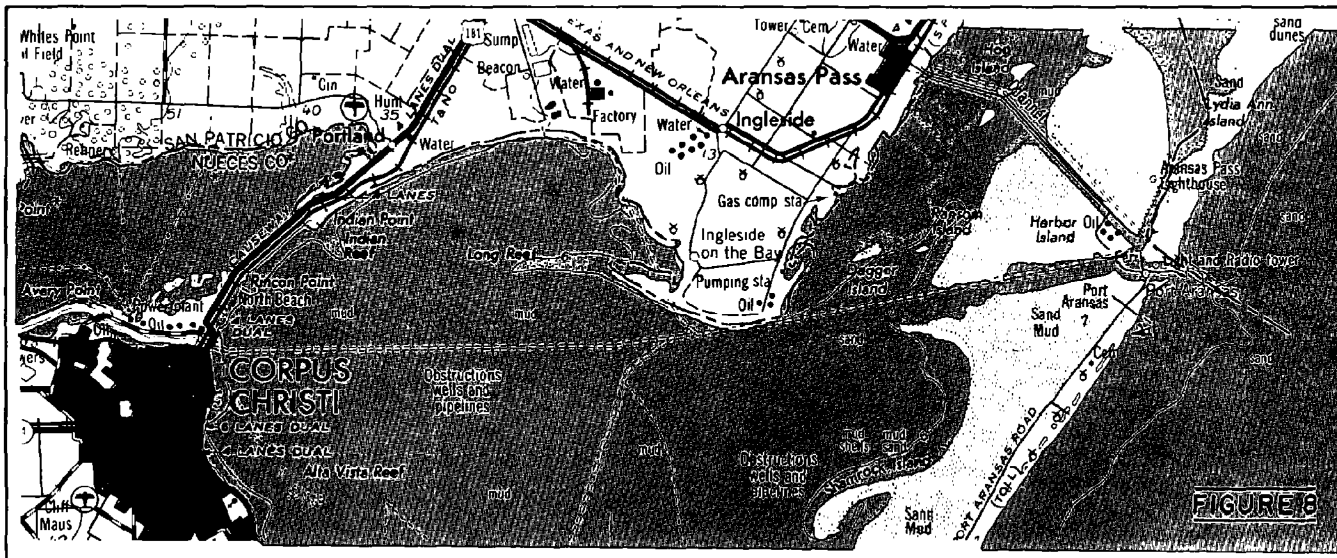
In summary, the maps presented herein show compiled and synthesized information on 11 themes. Each theme includes a map of the lower and upper coastal region so that a total of 22 maps are presented. The purpose of the map presentation is to illustrate graphically the complex ranges of natural and cultural interactions.



SCALE = 1:24,000 **1 in. ≈ 2,000 ft.** **AREA COVERED ≈ 3.25 sq. mi.**



SCALE = 1:62,500 **1 in. ≈ 1 mile** **AREA COVERED ≈ 27.5 sq. mi.**



SCALE = 1:250,000 **1 in. ≈ 4 miles** **AREA COVERED ≈ 340 sq. mi.**

THE INVENTORY, PART 1–PHYSIOGRAPHY AND CLIMATE

Physiography (terrain) and climate interact in the Texas coastal region so that eleven major river systems cut across a gently sloping coastal plain and empty either into a series of bays or directly into the Gulf of Mexico. Climate is progressively more arid along the Texas coast from the northeast to the southwest. Climatic factors influence the size of respective river basins, bay systems, and the presence of mobile, windblown sand sheets in South Texas.

Physiography is the description of terrain—hills and valleys, watercourses, shorelines—in other words, the "lay of the land." Climate is a long-term composite picture of weather conditions and atmospheric processes in an area. Climate and physiography interact. Landforms affect climate by the geographic positions of water bodies and shorelands with respect to prevailing winds, or by the location of topographically high areas that may induce rainfall or block the movement of moisture-laden air (fig. 9). Climate affects landforms by means of different erosion and weathering rates that are functions of the amount and temporal distribution of rainfall, degrees of insolation, wind activity, freeze-thaw frequency in winter, and other factors.

The interaction of climate and physiography along the Texas coast creates distinctly different regimes as one moves southwest from the humid upper coastal region to the lower coast (Pl. 1, A and B). The overall climate of the Texas coast is subtropical with long, warm to hot summers, and short mild winters (Kane, 1970). As one moves southwest along the coast, the climate becomes progressively more arid, and four climatic belts are apparent: humid, wet subhumid, dry subhumid, and semiarid (Thornthwaite, 1948). Mean annual temperature increases and rainfall decreases from the upper to the lower coast. In the vicinity of Matagorda Bay, there is a significant climatic boundary below which the potential evaporation exceeds the average annual rainfall. South of this boundary fresh water is a wasting asset. That is, water is in short supply within the lower coastal region.

An important climatic factor along the Texas coast is the recurrence of extraordinary climatic events such as hurricanes, tornadoes, or rainfall of high magnitude that may or may not be associated with hurricanes or tropical storms. Hurricanes strike the Texas coast on the average of once every 1.5 years (Price, 1956). Thus, a climatic hazard exists in the region, resulting in activation of various processes (geologic hazards) on the ground.

Physiographic features reflect climatic changes along the Texas coast. The diminishing size of bay systems from the upper to the lower coast reflects decreasing quantities of river inflows associated with decreasing rainfall. Another physiographic feature directly related to climate is the presence of mobile, windblown sand sheets in the lower coastal region, where hot, dry, prevailing winds blow across reaches of sparse vegetation, transporting sand and silt and depositing the material over a large area.

The primary physiographic features of the Texas coastal region are eleven major river systems. These are the Sabine, Neches, Trinity, San Jacinto, Brazos, Colorado, Lavaca, Guadalupe, San Antonio,* Nueces, and Rio Grande. In addition, there are numerous smaller streams that drain the "coastal basins" adjacent to lower courses of the major systems. Of the major rivers, only three—the Brazos, Colorado, and Rio Grande—flow directly into the Gulf of Mexico. These three rivers have filled their respective estuaries and exhibit a prominent delta plain. The other eight rivers flow into a series of bays separated from the open Gulf by barrier islands and peninsulas.

The major bay systems along the Texas coast include Sabine Lake, the Galveston-Trinity Bay System, the Matagorda-Lavaca Bay System, San Antonio Bay, the Aransas-Copano Bay System, Corpus Christi Bay, and the Laguna Madre-Baffin Bay System. Major barrier islands include Galveston Island, Matagorda Island, St. Joseph Island, Mustang Island, and Padre Island. Bolivar and Matagorda Peninsulas are the major peninsulas.

In the lower reaches of river systems and along bay margins there are broad expanses of wetlands, including saltwater marsh, freshwater marsh, and tidal flats. Astronomical tidal ranges are very low (less than 2 ft.), but extensive areas of low-lying lands are periodically inundated by wind-driven tides and storm surges.

The coastal uplands consist of a plain that slopes gently to sea level. Farther inland the sloping plain displays steeper slopes and more relief. The highest altitude in the coastal region is 540 ft. above mean sea level (msl), in Bee County.

*The Guadalupe and San Antonio Rivers flow together a few miles upstream from Guadalupe Delta and flow as one river into San Antonio Bay.


PHYSIOGRAPHIC AND CLIMATIC INTERACTIONS IN THE TEXAS COASTAL REGION
SABINE
TRINITY RIVER
BRAZOS
COLORADO
RAIN
WIND
HUMID
SABINE RIVER
TRINITY
EDWARDS PLATEAU
BALCONES ESCARPMENT
ESCARPMENT
BRAZOS
WET SUBHUMID
COLORADO RIVER
RIVER
OAKVILLE
PRAIRIE
DRY SUBHUMID
COASTAL
S.E. WINDS
GULF OF MEXICO
NUECES PLAIN
SEMIARID
PREVAILING S.E. WINDS
SAND PLAIN
RIO GRANDE
MEXICO
PREVAILING WINDS
N

FIGURE 9

THE INVENTORY, PART 2—SUBSTRATE

Substrate of the Texas coastal region consists predominately of river-laid sand and mud that occur in deposits of complex three-dimensional geometry. In addition to these sand and mud sediments, there are modern and ancient sediments reflecting various geologic settings and processes.

Substrate is rock or sediment material underlying an area. The upper limit of substrate is the soil zone in which bacterial activity, water, and other agents of weathering have interacted to produce a surficial medium capable of supporting plant life. Strictly speaking, the entire solid earth (beneath the soil zone) is substrate. However, for all practical purposes the concept of substrate is valid only insofar as man can reach (and use) earth materials at depth. Uses of substrate include support of foundations, mineral extraction, and waste emplacement.

The substrate display (Pl. 2, A and B) is a modified version of a geologic map. Basically it shows three things: (1) areal variations in materials occurring beneath the soil zone but near the ground surface, (2) clues regarding three-dimensional rock geometry, and (3) a historical presentation of earth materials in terms of their geologic ages. The first two are the most important for evaluating land resources.

The depiction of areal variations in materials assists the engineer or planner who must know about ground strength for foundations, about ground permeability for ponds and landfills, or about locating minerals at shallow depth. The three-dimensional view is of particular interest to one drilling water wells or seeking mineral deposits. The historical view of the earth is a more academic subject, although the age of materials has bearing on both areal engineering properties and the location of underground mineral deposits.

The substrate maps of the Texas coastal region are highly generalized. The predominant materials present are sand and mud intermixed in all gradations from pure sand to pure clay. These sand and mud deposits are generally soft and uncemented, although locally there are lenses or strata of hard rock. In the more arid reaches of the coastal region, a surficial cement of limy material (caliche) is common. The sand and mud deposits generally display an interlacing pattern both on the surface and at depth. These deposits, which trend roughly perpendicular to the present coast, result from river and delta deposition in the past. These depositional processes account for the bulk of the rocks and sediments along the present Gulf coastal plain. Local exceptions to the river-laid sands and muds are windblown sand sheets along the lower Texas coast, and remnants of ancient barrier and beach deposits. Modern bay-marsh, barrier-beach, and offshore areas are currently loci of sediment deposition.

The intricate, interconnected surface expression of former stream courses and ancient river deltas indicates that the precise demarcation of underground sediment geometry is impossible. The stream courses at depth occur in complex, interconnected or isolated lenses and strata (fig. 10). Although modern instruments give trained geologists clues regarding subsurface sediment geometry, the best these scientists can offer is qualified guesses based upon deep cores, well cuttings and logs, and geophysical profiles. Thus, drilling for groundwater or oil always involves an element of guesswork. There is always uncertainty regarding geometry, composition, or other properties of subsurface earth materials.

The substrate maps show major trends of sand, mud, and other sediments. However, at any given point within one of these localities the actual material may be at variance with the unit description. This variation might result from problems of scale, or it might be because of deficiencies in data at hand, such as in offshore areas where geologic surveys have not yet been conducted. Thus, these substrate maps should not be applied to site-specific problems. The maps are intended to focus attention on the major substrate components in an area, but more detailed mapping would be required to address local problems.

SCHEMATIC BLOCK DIAGRAM SHOWING COMPLEXITY OF SUBSTRATE RELATIONS AT THE SURFACE AND AT DEPTH IN THE TRINITY BAY AREA.

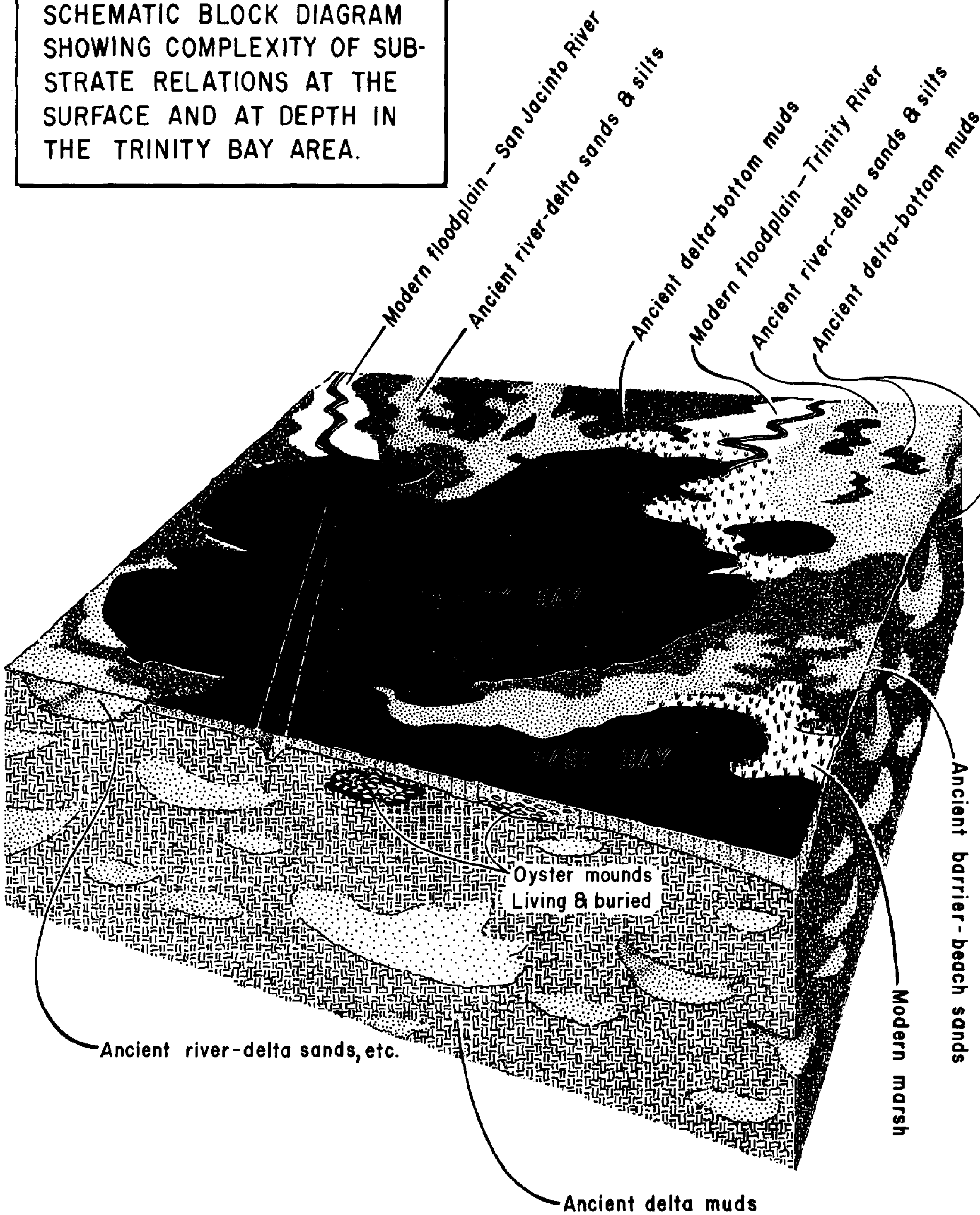


FIGURE 10

THE INVENTORY, PART 3—WATER RESOURCES

Water resources of the Texas coastal region are dependent on climate and substrate. Because of climatic vagaries, there are extreme variations (both geographically and through time) in quantity and quality of surface water. Substrate controls the locations of aquifer recharge, as well as water-yielding properties of aquifers at depth.

The oceans are the ultimate water resource; they contain the bulk of the earth's water. However, the total water resource picture is complex and dynamic. The oceans supply much of the atmospheric moisture, which eventually falls as rain or snow, is used by plants and animals, flows in rivers, or seeps underground. The interchange between oceans and atmosphere, and between atmosphere and land, is all part of a cycle in which water is not "lost" but changes form or locality (fig. 11). The irony of the water cycle is most apparent along the southern Texas coast where one is surrounded by water, but where potable water is scarce.

Ocean waters support transportation, commercial fishing, and recreation. However, ocean water cannot be used for most human needs without costly desalination. Thus, the freshwater resources of the coastal region are of special concern. Fresh water occurs in surface water bodies, such as rivers and lakes, and in subsurface rock or sediment deposits, termed aquifers. Variations in quality and quantity of freshwater resources occur as a result of climatic and geologic interactions. In an area of high rainfall, streamflow will be greater than in a similar area with less rain. In areas underlain by permeable substrate, surface water tends to seep into the ground. In hot dry areas, evaporation from surface waters may represent a sizeable water transfer. Locally, vegetation may consume significant quantities of water. Consequently, water resources are not equally distributed geographically, nor are they of equal natural quality.

In the Texas coastal region a dynamic interaction occurs between fresh and saline waters (Pl. 3, A and B). Fresh water flows into tidally-influenced reaches of water courses, called estuaries, where it mixes with salt water. These mixed water bodies comprise bays, estuaries, and tidal wetlands. Although the brackish waters contained in these tidally-influenced areas are no longer potable or usable on crops, these waters are important as sustainers of habitats for finfish, shellfish, birds, and other wildlife. Fresh water that flows into estuaries is an ecological resource of considerable importance, because estuarine areas are the bases for much of the marine food chain. Thus, water requirements for estuarine areas need to be considered just as are the needs for fresh water on the uplands. However, these "needs," like economic needs, cannot be readily computed.

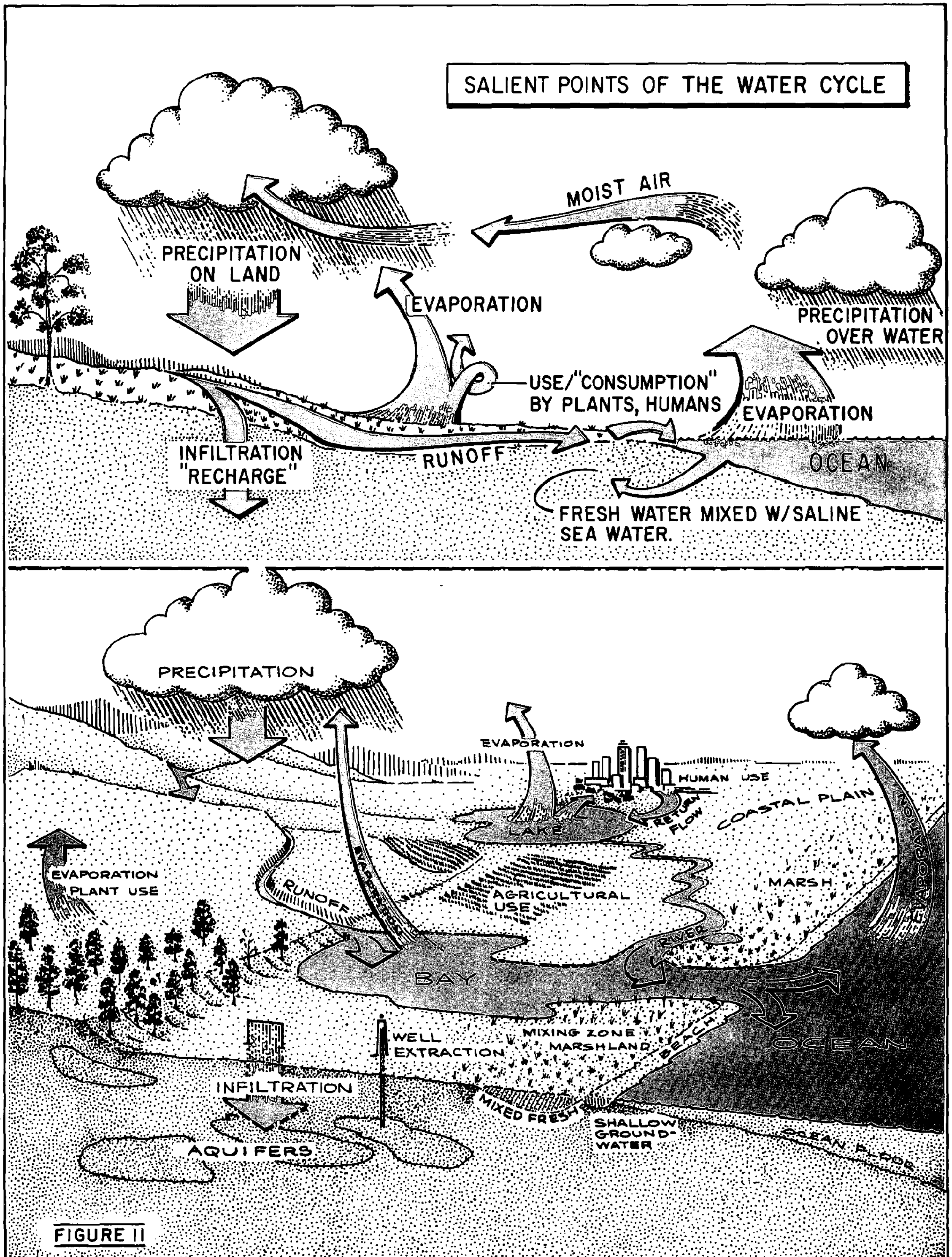
An inventory of water resources in the Texas coastal region can be viewed as a "water budget," drawing a rough analogy to financial accounting for income and expenditures. Unlike a family account, certain aspects of the water budget can be assessed only in terms of probabilities, as there are no certainties such as assured income and known expenses. This uncertainty is partly a result of the vagaries of climate, whereby an area may be subjected to years of drought only to have a flood of record occur overnight.

The "capital stock" or "savings" of this water budget includes groundwater and freshwater "stored" in lakes, rivers, and within fresh to slightly brackish wetland areas. Along the Texas coast, there are shallow aquifers on barrier islands and within river valleys, but these can supply only local water needs. A large volume of potable water occurs within the extremely complex sand deposits known collectively as the Gulf Coast aquifer. However, knowledge regarding this water source is not highly refined. The aquifer is so complex that its geometry at depth, its hydrologic properties, and the extent of its recharge area have not been adequately defined. Safe withdrawal rates have not been established for this aquifer. Without this knowledge "overdrafts" might occur that would deplete this groundwater supply or instigate deleterious effects such as subsidence. The remainder of this "capital stock" of fresh water—that is, surface water—is more easily assessed, although it, too, is part of a dynamic system that also changes continually.

"Income" from this water budget consists mainly of recharge and streamflow of major river systems. However, there is also transfer between accounts by groundwater pumping, spring discharge, and direct recharge from streamflow. Recharge rates are only vaguely understood, whereas streamflow is documented by quantitative data collected over many years. These data indicate that streamflow is variable and is dependent on climate. The greatest volumes of streamflow in the Texas coastal region are the discharges of a few rivers that flow across the humid upper coastal plain. Bay size, like streamflow, generally reflects climatic regimes.

Annual (or long-term) salinity values in the bays and estuaries indicate the quantities of "expenditures" in the water budget. In a sense, water that reaches the salinity levels of ocean water is "spent." It is still a resource, to be sure, but to meet man's and the wetlands' needs for fresh water, ocean water must be recycled through the processes of evaporation, rainfall, and runoff.

Fresh water is *the* limiting natural resource in the coastal region. There are competing demands for this vital resource among various systems—both natural and human. Conflicting systems include agriculture, industry, municipal-residential, and natural biotic. Further refinement of the water budget is needed for allocation of this resource. Especially needed is a more detailed accounting of the "capital stock" occurring in the large but ill-defined Gulf Coast aquifer.


SALIENT POINTS OF THE WATER CYCLE
MOIST AIR
PRECIPITATION ON LAND
EVAPORATION
PRECIPITATION OVER WATER
USE/"CONSUMPTION" BY PLANTS, HUMANS
EVAPORATION
INFILTRATION "RECHARGE"
RUNOFF
OCEAN
FRESH WATER MIXED W/SALINE SEA WATER.
PRECIPITATION
EVAPORATION
HUMAN USE
LAKE
RETURN FLOW
COASTAL PLAIN
EVAPORATION PLANT USE
RUNOFF
EVAPORATION
AGRICULTURAL USE
MARSH
RIVER
BAY
EVAPORATION
WELL EXTRACTION
MIXING ZONE MARSHLAND
BEACH
OCEAN
INFILTRATION
MIXED FRESH
SHALLOW GROUND-WATER
AQUIFERS
OCEAN FLOOR
FIGURE II

THE INVENTORY, PART 4—NATURAL PROCESSES

Natural processes are responsible for many of the continual changes on land and in water. Coastal processes include stream runoff, sediment deposition, shoreline erosion, storm surge, ground subsidence, faulting, and sand dune movement. Many of these processes pose hazards to human activities; yet rates, recurrences, and precise locales of hazardous processes remain uncertain.

Natural processes continue to shape the Texas coastal region. These processes include river discharge of water and sediment into the bays or directly into the Gulf, wave erosion of barrier island and mainland beaches, compaction and settling of newly deposited sediments, storm surges, wind activity, and river flooding resulting from high rainfall on the uplands. (Pl. 4, A and B) These processes are the agents of change. They ensure that the coastal region remains a dynamic area—that changes continue for shorelines, bays (in both areal extent and depth), marshlands, and river courses (fig. 12). These changes are vital to the maintenance of various biologic and physical systems. Floods flush the bays, and although this flushing may seem to have short-term adverse affects on biota, it is followed by increased biologic productivity. Hurricane-related rainfall supplies approximately 25 percent of the total precipitation to continental areas. Marsh changes ensure the continued cycling of nutrients essential to marine life. However, some of the changes conflict with human uses of the land. The conflicts usually occur where man has gotten in the way of natural processes, or where he has unwittingly upset balances which, in turn, have activated certain other processes. Ground subsidence because of extensive groundwater withdrawal is an example of man initiating processes.

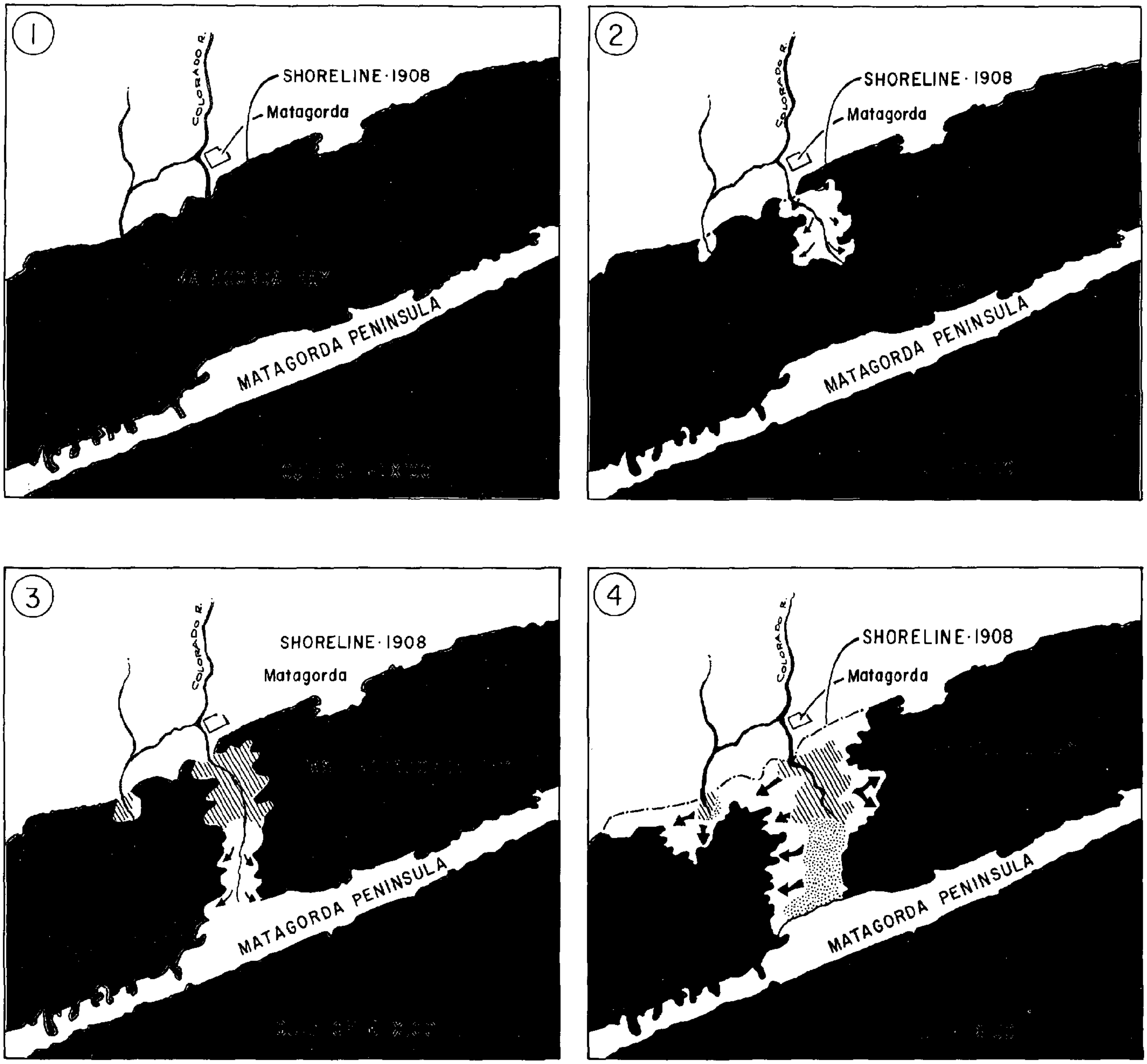
In some instances the impacts of processes can be arrested or mitigated, but generally the wisest action is to avoid areas that may be hazardous. A key point is that these processes are a result of *natural interactions* of climate, substrate, and water systems. The understanding of these interactions aids in delineating areas subject to natural processes, so that protective measures can be taken or hazardous areas can be avoided.

Many physical processes are water-related, presenting a duality in the nature of water. Water is a vital resource, but it may also be the agent of process and thus an agent of harm to human life and endeavors. Storm surge, river flooding, shoreline erosion, compaction of sediments, and ground subsidence are all water-related processes. Even some instances of faulting (breakage and displacement of rock material) and ground failure (landsliding) are indirectly related to the water content of sediments or soils. Indeed, the processes of wind activity and subsequent movement of mobile sand sheets (dunes) are water-related. They occur on a large scale only in the absence of adequate rainfall that supports stabilizing vegetation.

Some processes are recurrent and some are continually active, although rates may be so slow that the processes are discernible only over a long time period. Some processes combine both recurrent and continuous (incremental) factors. For example, a reach of a river may be eroding at small yearly incremental rates only to have an extraordinary natural event, such as a storm, cause more erosion in a single day than in decades preceding. The hazards of recurrent processes are often difficult to demonstrate until it is too late. A river may appear placid and not overflow its banks significantly for years. Yet, given one extreme climatic event, it can become a raging torrent. Recurrent processes in the Texas coastal region include storm surges and river flooding. The principal incremental processes are ground subsidence and faulting.* Recurrent-incremental processes include erosion and sediment deposition.

There is a continuing debate about the precise limit of hazardous areas. If the process is recurrent, some precise statement of recurrence is demanded. These problems cannot be resolved with certainty. Hazardous processes result from the interactions of multiple variables, each one of which—climate, substrate, soil conditions, prior river flow conditions or tidal conditions, and ambient human activities—is extremely complex. The complexity of natural systems has prevented their being adequately modelled, and it is impossible to predict exactly where or when future catastrophic events will occur. Certain areas are *more probable* loci of hazardous processes—the river bottomland is the likely locale for flooding, whereas uplands are relatively secure. Still, the *exact limits* of areas subject to hazardous processes cannot be drawn. For example, flood-prone areas can be delimited based on the fact that they have been flooded in historical time, or that they show features indicative of past flooding. However, delineating an area that will flood within a presumed time interval is beyond the limits of scientific and engineering precision. A historical judgment can be made—an area can be marked as flood-prone because it has been flooded in the past. However, future projections of exact process boundaries must be largely speculative.

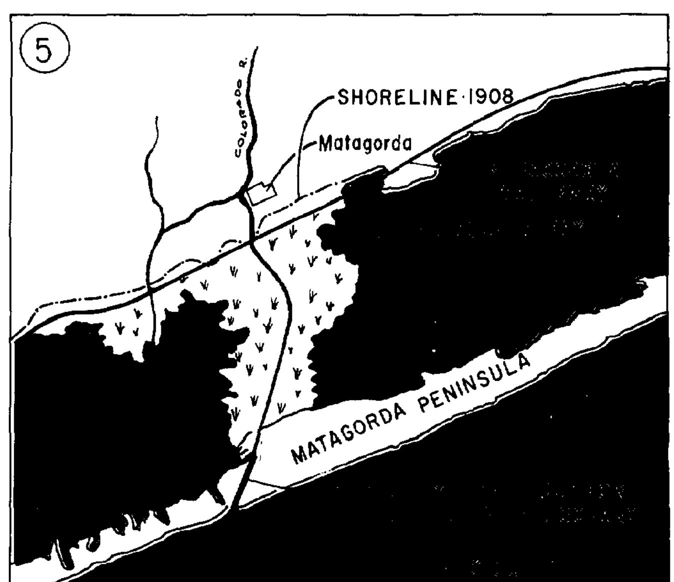
*Fault movement along the Texas coast does not result in earthquakes, a recurrent hazard in California. Instead, the soft sediments merely slide slowly and continually along the plane of breakage.



SEQUENTIAL CHANGES IN MATAGORDA DELTA SHOWING MAN'S EFFECTS ON NATURAL PROCESSES (AFTER McGOWEN AND BREWTON·1975)

1. COLORADO RIVER MOUTH (IN MATAGORDA BAY), IN 1929, BEFORE LOG JAM WAS REMOVED.
2. COLORADO DELTA·1930
3. COLORADO DELTA·1936
4. COLORADO DELTA·1941
5. SCHEMATIC PRESENTATION OF COLORADO RIVER MOUTH AS IT PRESENTLY EMPTIES INTO THE GULF OF MEXICO.

FIGURE 12



THE INVENTORY, PART 5—SOILS

Soils constitute the base for agricultural endeavors, and in the coastal region, agriculture is a significant economic sector. Soils are also indicators of general environmental interactions among substrate, climate, topography, processes, biota, and human influences.

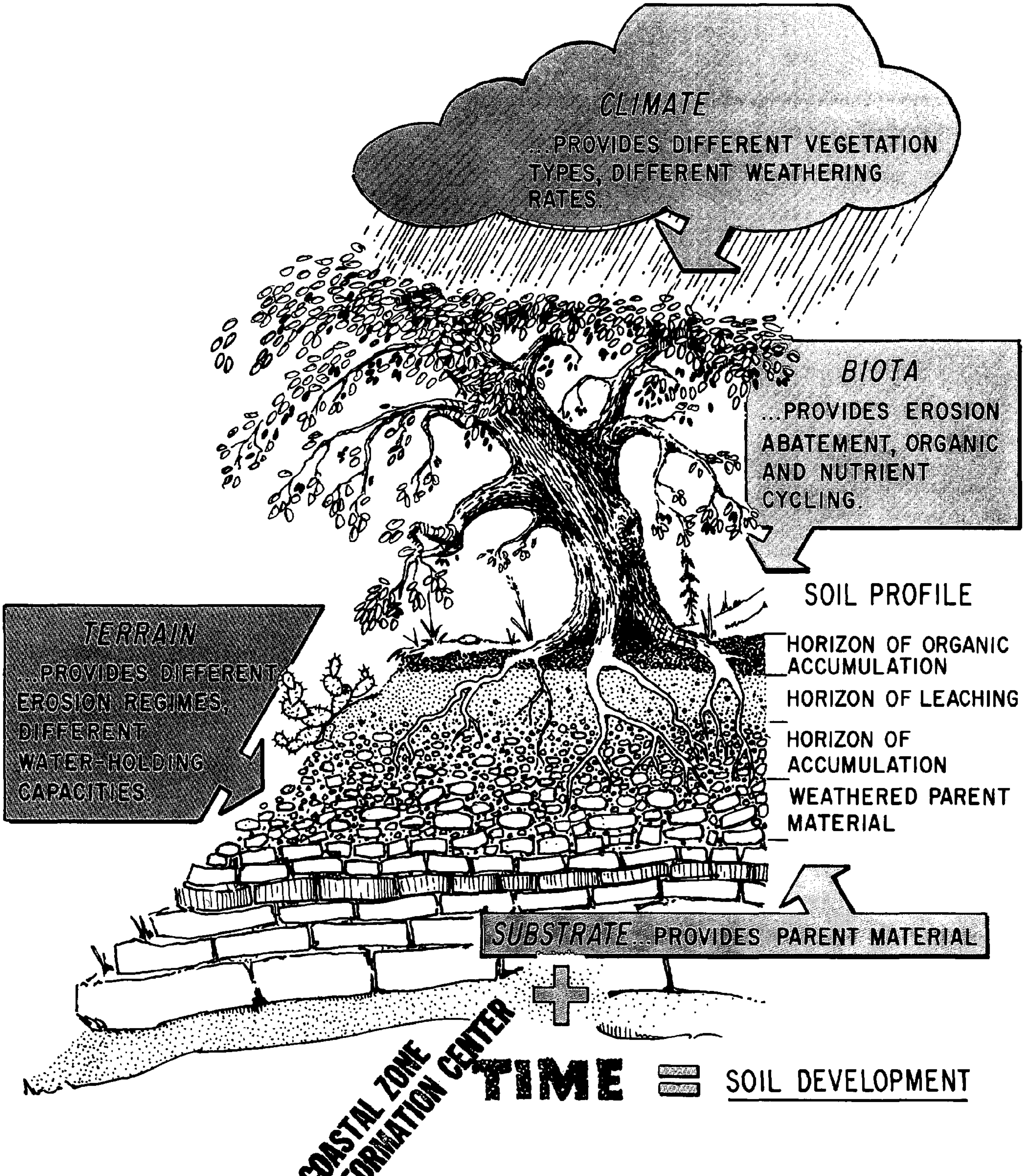
Soil is solid, surficial earth material that is capable of supporting plant life. As such, soil—along with air and water—is one of the basic sustainers of life. It directly or indirectly supports all terrestrial life, including man.

Soil originates as a result of dynamic interactions among several factors: substrate, climate, topography, and biota (fig. 13). The result is a complex mixture of solid inorganic materials, fluids (solutions of minerals and gases in water), and biologic components (both living organisms and dead organic matter). Soils change continually according to water availability, nutrient cycling rates, kinds and extent of plant cover, human activities, and many other factors. Most soil changes are slow in relation to human experience, perceptible over decades rather than days. However, certain events such as floods, droughts, and fires can markedly change soil conditions in a brief span of time (for example, by accelerating erosion). Regeneration of a soil lost because of natural processes or depleted by unwise land use practices is a slow process—so slow that soil is, in effect, a nonrenewable resource. Man can rapidly deplete the soil, or he can mitigate some of the damaging processes (whether naturally-occurring or man-induced). It is clearly in his best interest to practice stewardship regarding this resource. Soil will continue to support mankind only insofar as mankind sustains the soil.

Soils function as indicators of environmental potentials, pressures, and adversities. Soils riven by gullies or depleted of nutrients indicate that demands are being imposed beyond natural sustaining capabilities. Slightly saline soils near the coast indicate the effect of tidal influence, shallow saline groundwater, or the activity of wind-driven salt spray. Saline soils in upland areas may reflect extreme arid climatic conditions. Soils along active river courses are incrementally augmented (and locally damaged) by sediments deposited during floods. Soils lying in humid regions are progressively more leached of nutrients than soils occurring in more arid areas.

Soils are derived mainly from an underlying geologic substrate. The surface processes of weathering, acting through time, combine climatic and biologic factors and tend to rearrange the original substrate components. Soluble materials are carried away in solution, and fine-grained residue is segregated from coarse-grained detritus. Biologic factors affect soils as both ingredients and as processes in soil formation. Thickness, texture, structure, and composition are the bases for soil classification and ultimately for mapping soils. The maps can be used to infer environmental conditions that result in a certain suite of soils, or they can be used to interpret the history of soils in a given area. More importantly, a soil map can show areas best suited for producing food and fiber. Soil maps are also commonly used for judging other constraints or possibilities regarding use of the land.

The specific crops grown in a locale are largely determined by the type and quality of soil present and by climatic factors. The Texas coastal region produces the bulk of the U.S. rice crop (in the middle and upper coast) and significant portions of the nation's citrus (in the Lower Rio Grande Valley). In addition, assorted other fruits and vegetables are produced throughout the winter from the lower coast; cotton and grain sorghum are produced from the lower and middle coast; and the entire region supports an important cattle industry. Thus, the soils of the Texas coastal region (Pl. 5, A and B) are a notable agricultural resource.



MAJOR FACTORS AFFECTING SOIL FORMATION

FIGURE 13

UPLAND NATURAL AREAS

Soils afford a means for synthesizing diverse environmental influences and for grouping major types of land on the uplands. The upland natural areas in the coastal region include tidelands and coastal lowlands, windblown sand sheets, river bottomlands, prairies, dissected prairies, and woodlands.

Several major classes of soil can be combined according to their capabilities for potential agricultural uses.* Major soil groups such as those presented herein reflect certain environmental factors, namely climate, substrate, natural vegetation, and terrain features; the composite of soils and other factors results in the designation of a series of upland "natural areas" (fig. 14).

One natural area includes the lowlands directly adjacent to the open ocean or bays. These lands are characterized by saline, sandy, or muddy soils. They include the barrier island complexes (sandy soils) and tidally-influenced wetlands and adjoining areas that are poorly drained and have a high organic content. This land type is marginally acceptable as an agricultural resource and is used sparingly as rangeland. However, it may be more important not as an agricultural resource, but as wildlife habitat (especially in marshy areas), or as the supporter of grasses that stabilize dunes on barrier islands. This natural area comprises three major soil units (Pl. 5, units V, IX, and X).

Another natural area is the broad expanse of loamy soils (Pl. 5, unit III) occurring mainly along the inland part of the lower coast in Kenedy, Kleberg, and Willacy counties. This soil unit corresponds to windblown sand sheets. These soils are subject to wind erosion and locally to salt spray. The climate is semiarid, and the land is only marginally suited for cultivation, although it is important range country. If more water were available, this land might support a greater variety of uses.

River bottomlands constitute a natural area consisting of one major soil unit (Pl. 5, unit XV). This area is characterized by periodic flooding with attendant siltation on the floodplain and local erosion of stream channels and banks. The characteristics of this land type change as one moves from the humid upper coastal area to the semiarid lower coast. In its natural condition, this land type is commonly covered with trees. Along lower stream reaches, tidal marshlands are prevalent. Except for periodic flooding and locally poor drainage conditions, much of this land is arable. Although it is not the best agricultural land in the region, it is generally adequate. It is intensively cultivated, especially in the Lower Rio Grande Valley.

Prairie terrain is the largest natural area in the coastal region. Prairies are natural grasslands with local inclusions of trees or brush. The landscape is gently rolling or consists of nearly level topography above river courses and tidal influences. Soils occurring on this terrain support some of the most intensive agricultural activity in the region. Soil units comprising the prairie region (Pl. 5, predominantly units I, II, and IV) have variable properties, but they are generally clayey to loamy in texture. The high water-holding capacity and low permeability of certain prairie soils are important criteria for coastal rice production. Prairie soils commonly present problems for nonagricultural uses. Poor drainage and a high shrink-swell potential combine to inhibit many construction activities unless extensive and costly mitigation attempts are undertaken.

The remainder of the coastal region consists of dissected prairie lands and woodlands. Dissected prairies include some of the premium rangelands of the region, partly because slightly higher slopes make the terrain less amenable to cultivation. Soils in this natural area (Pl. 5, mainly units VI, VII, VIII, XI, and XIV) are commonly clayey and loamy (less commonly sandy, stony, and loamy). Lime accumulations (caliche) are a widespread component of the soil profile in the lower coastal region.

The woodlands of the upper coastal region make up a distinct natural area based mainly on native vegetation. These soils (Pl. 5, chiefly units XII and XIII) are commonly loamy and locally clayey at the surface or at depth, so that poor drainage conditions may pose problems in some areas. Woodlands support mainly forest biologic assemblages, although the land is used locally for range, cultivation, and urban-residential-industrial activities.

In summary, soil resources of the Texas coastal region are highly varied and basic to the upland natural food chain. Composite natural upland areas based largely on major groups of soils also demonstrate the numerous environmental factors that interact in the coastal region: substrate, processes, climate, topography, and vegetation.

*The description of soils characteristic of specific areas along the Texas coast is derived from the *Coastal Basins Study* by the U.S. Soil Conservation Service (SCS). Soil unit classes (denoted by Roman numerals) correspond to units presented in the SCS study.

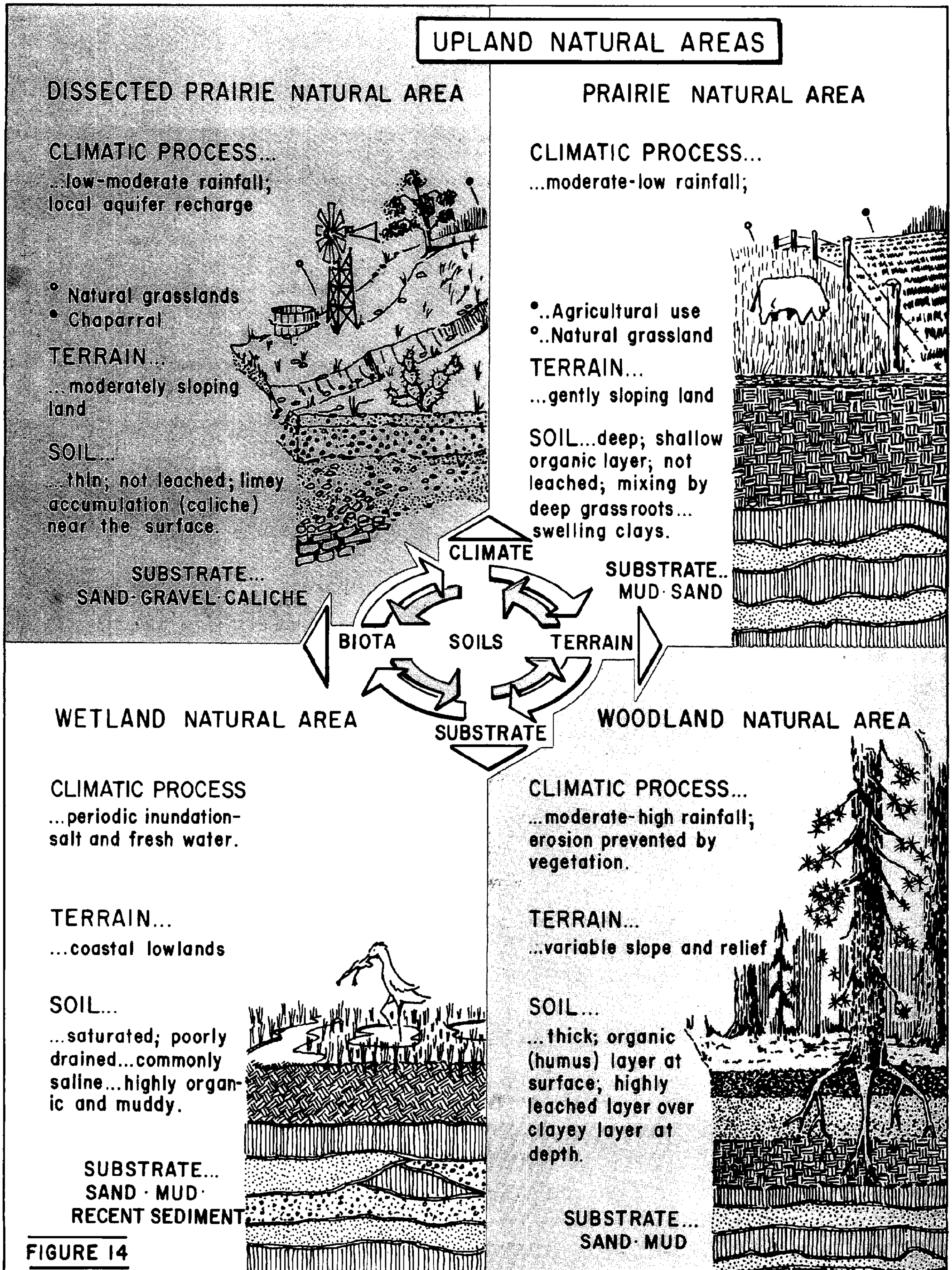

UPLAND NATURAL AREAS
DISSECTED PRAIRIE NATURAL AREA
CLIMATIC PROCESS...
...low-moderate rainfall; local aquifer recharge
° Natural grasslands
• Chaparral
TERRAIN...
...moderately sloping land
SOIL...
...thin; not leached; limey accumulation (caliche) near the surface.
SUBSTRATE...
SAND-GRAVEL-CALICHE
PRAIRIE NATURAL AREA
CLIMATIC PROCESS...
...moderate-low rainfall;
•..Agricultural use
°..Natural grassland
TERRAIN...
...gently sloping land
SOIL...deep; shallow organic layer; not leached; mixing by deep grassroots... swelling clays.
SUBSTRATE..
MUD·SAND
CLIMATE
BIOTA
SOILS
TERRAIN
SUBSTRATE
WETLAND NATURAL AREA
CLIMATIC PROCESS
...periodic inundation-salt and fresh water.
TERRAIN...
...coastal lowlands
SOIL...
...saturated; poorly drained...commonly saline...highly organic and muddy.
SUBSTRATE...
SAND · MUD·
RECENT SEDIMENT
WOODLAND NATURAL AREA
CLIMATIC PROCESS...
...moderate-high rainfall; erosion prevented by vegetation.
TERRAIN...
...variable slope and relief
SOIL...
...thick; organic (humus) layer at surface; highly leached layer over clayey layer at depth.
SUBSTRATE...
SAND·MUD

FIGURE 14

THE INVENTORY, PART 6—BIOLOGIC RESOURCES

Biologic resources of the Texas coastal region include plants and animals occurring on land and in water. Man tends to designate certain "key" organisms as important, either as food resources (e.g., fish and shellfish) or as recreational resources (e.g., game, sports fish, and fowl). However, man must also understand the total ecologic picture in which these "important" species are only a part of an interconnected "web of life."

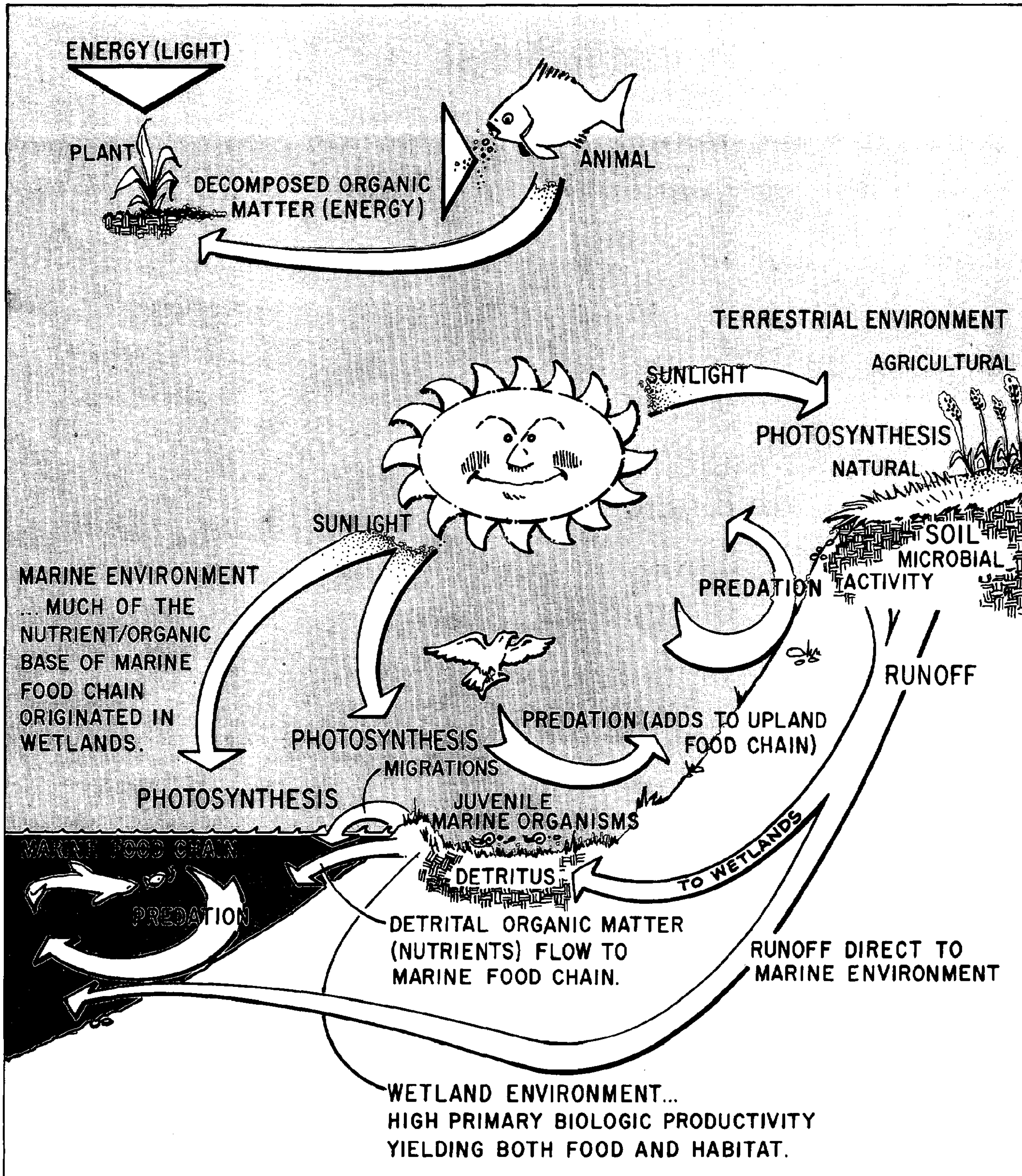
Biologic resources encompass the total array of organisms (plants and animals) native to any area. This definition distinguishes "wild" (or "natural") biota from such "tame" living systems as crops, livestock, and man. Biota interact with and adjust to all other elements of the local environment: different climatic zones, different soil types, different terrains, different water conditions, and different processes. Biota also adjust to environmental extremes such as storms, floods, droughts, fires, and intensive human modification of the land. The "adaptation" to the multifaceted array of environmental conditions simply means that some species survive and prosper in a given set of conditions, whereas others (under identical conditions) die out or move elsewhere. Over extremely long time periods, specific life-forms have adapted to almost all kinds of conditions, establishing "ecological niches" that reflect a complex interplay among diverse natural factors. The study of these interactions is what the discipline "ecology" is all about.

There are ecological niches for organisms living on mountaintops and ocean floors, in swamps, forests, and plains, and in rivers and bays. The same holds true for assemblages of organisms living in soil, on bare rock, in water, in air, and within other organisms. There are living systems built upon other systems—parasite-host, predator-prey, primary producer-consumer, scavengers, and autotrophs (organisms that synthesize their food from inorganic sources). There are fragile life forms, and there are those that are extremely resilient and persistent. In short, within an area there is an intricate "web of life" that consists of the interaction among various components—both living and nonliving, both organic and inorganic.

In a large sense, the various habitats and occupants thereof also interact. For example, there is an energy flow and a cycling of nutrients and other material from upland prairies and forests into the water courses and ultimately into the marine food chain. All environments (that is, composite natural areas) are linked together through time in a physical sense, via processes, materials, and energy transfers. Likewise, organisms from one habitat can markedly affect organisms in a different and seemingly unrelated habitat. Such an effect can be direct, as by periodic incursion of a predator; a pelican temporarily entering the fish's habitat (the ocean) is a good example. Or the effect can be indirect and subtle, such as prairie grasses abating upland erosion. This can decrease stream sediment, which may ultimately benefit oysters in a coastal bay. This flow of energy and material is all part of continuing biogenic cycles that transcend both plant and animal kingdoms, both terrestrial and aquatic environments (fig. 15).

Living things in all their diversity affect man and his endeavors. Human survival depends on organisms that commonly escape notice. They include microbes that ensure continued soil fertility, algae and planktons that form the base of the marine food chain (and continually augment the atmosphere's oxygen supply by means of photosynthesis), grasses that stabilize both sand dunes and soils and also aid in moisture retention on land, and fungi and bacteria that decompose organic wastes. Man also depends on larger, more visible biologic entities, such as fish, wildlife, fowl, and their respective habitats. These larger entities are the bases for commercial fishing and many other outdoor sporting activities including merely "enjoying scenery." Not surprisingly, these larger biologic entities also depend on the above-mentioned lower life forms.

Finally, it is true that man impacts biota. Knowledge of these impacts and their effects, both benign and adverse, is critical to the proper management and to the assured survival of many types of key organisms. Maps showing areal extent of these biologic resources (Pl. 6, A and B) aid in understanding and managing these resources.



SCHEMATIC FLOW OF ENERGY AND MATERIALS IN BIOLOGIC SYSTEMS

FIGURE 15

HABITATS AND ENVIRONMENTS

Environments are areas in which natural factors—climate, water, soil, substrate, physical processes, biota, and human activities—interact to produce a diagnostic set of ambient conditions. These conditions provide the basis for habitats for species adapted to their environments. Habitats for specific organisms may comprise all or part of any given environment, or they may include all or parts of numerous different environments.

An animal's living-space is its habitat, and organisms cannot be divorced from their habitats and survive. Humans may espouse a policy to ensure continued natural productivity of a species. Such a policy might entail regulation of harvest, or limitations of kills in terms of numbers of organisms or allowable seasons for harvests. However, if the habitat of the organism is lost, then the organism cannot survive. Although biota are considered a renewable resource, the habitat necessary for sustaining a given species may be (for all practical purposes) nonrenewable. Thus, there are basic information needs for managing biologic resources:

(1) To identify the life-forms that are deemed important to man (these can be the "visible" or direct assets, such as game and fish).
(2) To relate these "important" biologic entities to their habitats.
(3) To understand the interrelationships among these designated life-forms and the total environment, especially regarding the complete food chain and the linkages with inorganic systems and energy sources.

These information needs are being addressed by the Texas Coastal Management Program, drawing initially upon the expertise of the Texas Parks and Wildlife Department.

The biologic resource inventory of the Texas coastal region (Pl. 6, A and B) involves a complex array of map units showing environments and habitats for both upland and aquatic areas. Wherever practicable, both floral and faunal (plant and animal) assemblages have been included.

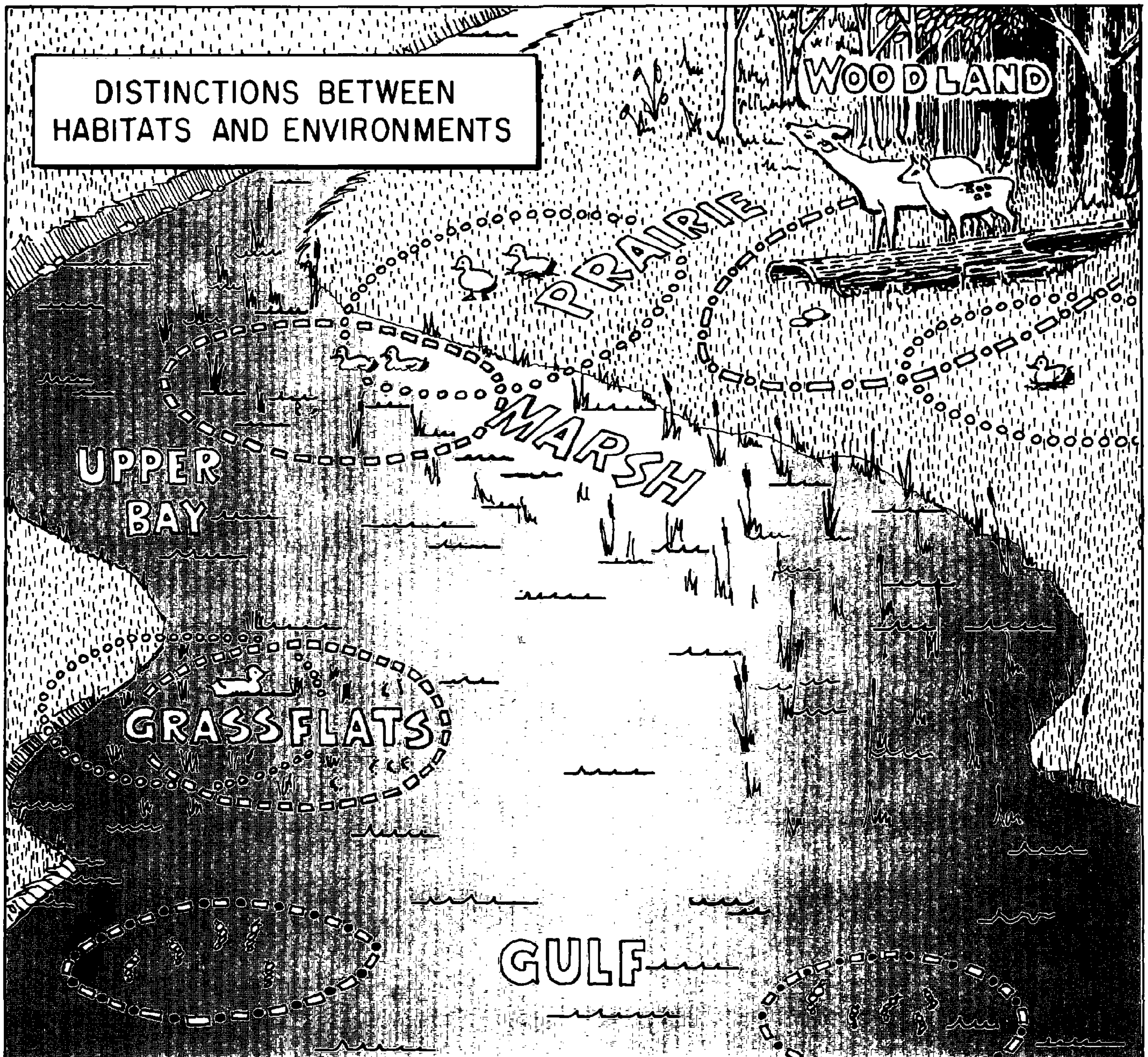
Environments represent a composite of ambient characteristics of the land—involving specific conditions or ranges in conditions of climate, water supply (both quality and quantity), substrate or soil, physical processes, human activities, and biotic interactions. Examples of upland (terrestrial) environments include different kinds of prairies, river bottoms, forest types, and chaparral or deserts. Examples of environments occurring in submerged or transitional areas include various types of marshes, grass flats, algal encrusted tidal flats, different bay regimes, and offshore natural areas. These aquatic environments are defined by diagnostic salinity ranges, bathymetry, substrate, or by characteristic biologic entities. For example, the presence of certain salt-tolerant grasses is indicative of salt marshes, whereas other grass species imply the presence of other marsh types.

A distinction should be made between the terms environment and habitat (fig. 16). The habitat of a species is the kind of environment(s) in which the species occurs. Habitat for juvenile brown shrimp is often found in grassflats, salt marshes, brackish to freshwater marshes, and river-influenced bays. Thus habitat for one species can span several environments. However, a habitat does not necessarily comprise the entirety of an environment. Usually, juvenile shrimp found in a river-influenced bay do not occupy the whole environment. They are found close to the land-water interface and near the river mouth.

Habitat for a species may be described as all or part of a natural environment or environments. Habitat is specific for the ecological niche of a species. It depends on the physical, chemical, and biological needs of the organism, and the way in which the species population is specialized. Habitat may change seasonally or annually because of chemical or biological fluctuations in the environment, or because of the developmental stage or age of the organism.

It would not be useful to speak of a shrimp environment. There is no one naturally occurring environmental unit where shrimp are found most of the time. It *is* useful to speak of grassflats as environments, since seagrasses occur almost exclusively in these areas during much of the year, and the environmental characteristics of the area are closely linked to the presence of these plants.

The complexity of migrations and the numerous life stages within many species result in a complex habitat array. Thus, the habitats of only selected biota are presented on the maps and are superimposed on environments of uplands and aquatic areas.



SPECIES	HABITAT	ENVIRONMENT
JUVENILE SHRIMP	LOW SALINITY, SHALLOW, GRASSY OR MARSHY AREA	MARSH GRASSFLAT UPPER BAY
ADULT SHRIMP	OCEANIC WATER	GULF
WATERFOWL	WETLANDS	MARSH COASTAL PRAIRIE GRASSFLAT
DEER	BRUSHY AND WOODED AREAS	WOODLAND BRUSHLAND COASTAL PRAIRIE

FIGURE 16

THE INVENTORY, PART 7—POTENTIAL MINERAL RESOURCES

Mineral resources of the Texas coastal region include local occurrences of high-value materials, such as oil and gas. There are also more widespread deposits of certain bulk-rock products necessary for the construction industry. Both kinds of resources are finite. If growth is to be sustained, both types of resources must be obtained and delivered to their respective markets.

Potential mineral resources include that part of substrate in an area that may yield a material of economic value to man. Minerals represent a base for modern industrial society, touching our lives every day in countless ways. Minerals are the raw materials from which the bulk of our cities are constructed—aggregate and asphalt for roads and concrete, brick, stone, steel and glass for buildings. In addition, minerals provide aluminum, copper, chrome, lead and fuel for automobiles; fertilizers for food and fiber; raw materials for synthetic fibers and plastics; chemical feedstocks; and many other products.

Minerals are nonrenewable resources. Unlike crops, livestock, fish, wildlife, forests, and water, minerals are not regenerated (or recycled naturally) at a rate approaching the rate of extraction or consumption. Thus, the extraction of minerals depletes this finite resource. Some recycling of certain metals by man is possible, but most mineral resources, once extracted, are effectively consumed.

The term "potential mineral resource" is based mainly on prevailing economic conditions. That is, depending on the market value of a mineral commodity, there is a certain lower limit of concentration of the mineral, a limit of depth of burial, or a limit of distance from the place of use that dictates whether a particular deposit is economically productive.

There are two broad classes of minerals, based on valuation by society and locational aspects of mineral occurrence. One class has a high inherent value regardless of location. These are generally low bulk commodities for which transportation to market is a small fraction of their total value. Petroleum is a good example of this mineral class. The other class derives its value partly because of the quality of the material and partly because of proximity to a market. These include the construction raw materials that are mined in bulk and for which transportation costs are a significant part of the price a consumer pays. Examples of this mineral type are sand and gravel, and crushed stone.

The Texas coastal region contains minerals of both types (Pl. 7, A and B). Low bulk, high value commodities found along the coast include petroleum, sulfur, and salt. High bulk mineral commodities in the region include sand and gravel, caliche deposits, and local clay deposits (that are processed into light weight aggregate, brick, or tile). Oyster shell has traditionally supplied material for aggregate and for the manufacture of lime. However, oyster shell deposits (dead reefs) suitable for mining are now largely depleted.

The areal distribution of these potential deposits shows salt, sulfur, and petroleum seeming to coincide or overlap in map view (Pl. 7) with sand and mud substrate. This overlap demonstrates the three-dimensional mode of occurrence of minerals (fig. 17). As mentioned in the section on substrate, the bulk of earth materials present beneath the Texas coast consists of complex three-dimensional deposits of sand and mud. Locally, oil and gas occur within sands. Also, salt has locally intruded overlying sediments, forming salt domes with associated occurrences of sulfur, gypsum, and petroleum. The wedge of sand and mud sediments in the Texas coastal region is more than 50,000 feet thick, which is much deeper than the world's deepest mine. The minerals existing at such great depths cannot be extracted economically unless, like petroleum, they can be extracted by means of well technology. However, the layered aspect of minerals—with sand and gravel being extracted at the near surface, petroleum produced at depth, and perhaps salt (brine) and Frasch sulfur pumped from a subjacent salt dome—demonstrates the complexity and the uncertainty regarding exactly what is beneath the ground. In brief, the extent of potential mineral resources presented herein (Pl. 7) is a simplified depiction of minerals occurring both at the earth's surface and at great depth.

Whereas petroleum is a mineral that may excite the imagination, the construction minerals—bulk rock products—are not so glamorous and are commonly relegated to the status of a second class commodity. This is unfortunate, as bulk construction materials—sand and gravel for aggregate and stone for lime and crushed aggregate—are very important economically and are demanded in huge tonnages by growing cities. The statewide average consumption for construction materials is about seven tons per capita per year. Yet high quality concentrations of sand and gravel or stone occur only locally; they are by no means ubiquitous. Unfortunately the potential mineral resource map of the Texas coastal region does not fully reflect the occurrence of these essential minerals. This failure is a result of an incomplete regional assessment of near-surface deposits potentially suitable for use as construction material. It is also partly a result of the restrictions imposed by the small scale map; sand deposits are not discriminated in terms of the amount of coarse-grained fractions (an important criterion to the civil engineer). Also the map does not differentiate "mud" deposits in terms of purity or mineralogy of constituent clays. Therefore, all sand and mud deposits are mapped as potential economic resources. However, most such occurrences are not suitable for large-scale production of aggregate, brick and tile, or any one of a number of specialty uses.

Construction rocks and minerals, upon which the coastal metropolitan regions depend, are extracted far from the coastal region. Sand and gravel for metropolitan Houston is transported about 100 miles. Crushed stone is shipped twice that far. For these resources, transportation costs exceed the basic commodity cost. This is important for estimating future costs of public works. It also affects private investment related to growth in coastal cities.

SCHEMATIC BLOCK DIAGRAM SHOWING THREE-DIMENSIONAL OCCURRENCE OF MINERALS WITH APPARENT OVERLAP OF DIFFERENT COMMODITIES.

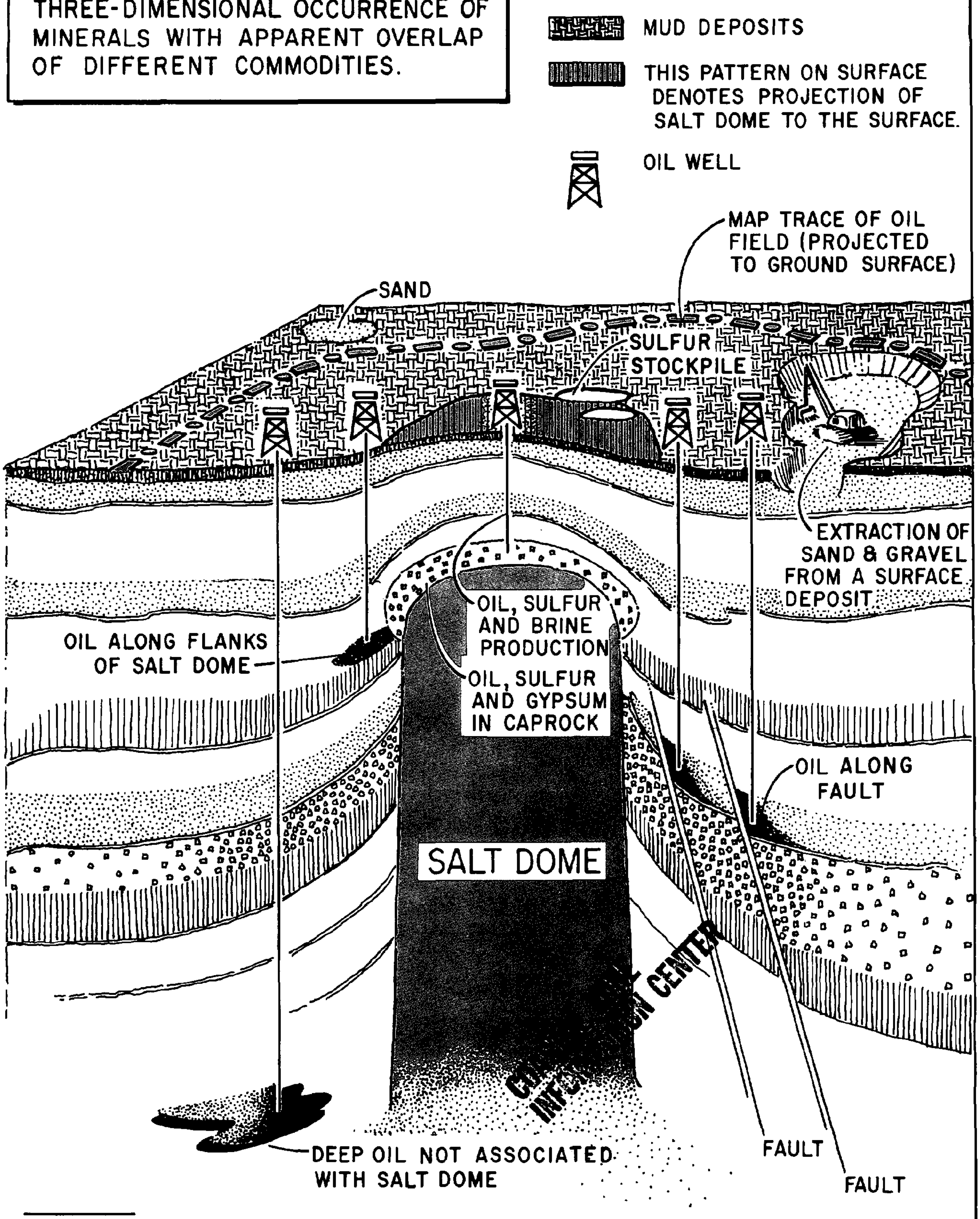


FIGURE 17

THE INVENTORY, PART 8—HISTORICAL-ARCHAEOLOGICAL OVERVIEW

Historical and archaeological surveys cover only a small part of the Texas coastal region. Historical and archaeological sites are relics of history or prehistory which may be valuable to modern man for many reasons.

Archaeological evidence suggests that man first came to the Texas coastal region about 12,000 years ago. At that time, the glaciers of the last great ice age were waning, and sea level was several hundred feet below its present stand. The Gulf shoreline was many miles from the present coast; the modern bay systems were broad river valleys; and much of today's shoreline consisted of inland prairies.

Early man was attracted to the water courses. He lived along the rivers in order to have an assured water supply and transportation route, but also to have a strategic location for hunting game attracted to the river courses. The earliest inhabitants were probably nomadic hunters who depleted game in one region and then moved on. They left scattered artifacts and a few kill sites that mark their presence. Many of their remains probably lie beneath the bays and offshore beneath the waters of the Gulf of Mexico in areas that were once dry land. These earliest inhabitants may have imposed extreme impacts on the environment. It is thought that these early hunters used fire to stampede and kill large numbers of mammoths, camels, bison, and other animals, many species of which subsequently became extinct (Martin, 1967).

Later on, other bands of primitive men immigrated and adapted to a coastal niche. By this time (about 4,000 to 5,000 B.C.) the sea had risen almost to its present level. The bays and barriers as we know them were forming. These people were hunters and gatherers who depended on coastal resources that were very different from those exploited by the earlier big game hunters. They began to develop regional social systems that are reflected in their artifacts, shell middens, and burial grounds, but they probably did little to alter the land. There was little technology to impose environmental impact; there was fire, but there were no horses and no wheels. Impacts, such as existed, were limited to dwelling sites occupied for a time and then abandoned. After abandonment, the land regenerated naturally; the impacts were not lasting.

Then, as now, the resources of the coastal region attracted inhabitants who were subjected to recurrent natural hazards. These early inhabitants were more intimately affected by the dynamic coastal processes, for they were without the means of coping that modern man has. Still, however harsh certain natural forces may have seemed, the coastal region offered an attractive array of resources: abundant food sources in game and fish; native vegetation along fertile river bottoms; water courses; a pleasant climate; and adequate dwelling sites away from mosquito-infested swamps.

Modest advances in lifestyles were made by coastal inhabitants throughout prehistory. Later groups introduced ceramics and the bow and arrow. Agricultural practices were probably known from neighboring groups, yet most of the tribes were still hunters and gatherers when Cabeza de Vaca landed on the Texas coast in the 1520's.

The Spanish colonial period had little impact on the coastal region, except for territorial conflicts with the French that resulted in the brief establishment of missions and garrisons at points of French encroachment into Texas. The Spaniards occupied only a few scattered permanent settlements, mainly in and around San Antonio, Goliad, and Nacogdoches. A major Spanish legacy in the coastal region lies under several fathoms of water off the coast of Padre Island and beneath certain shallow bays. This legacy is composed of sunken galleons laden with Aztec gold and silver and artifacts of another age.

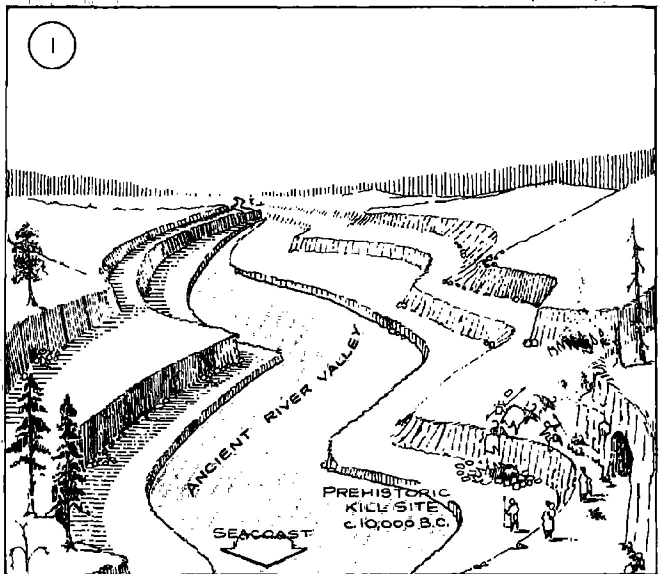
Mexican independence opened up the vast reaches of Texas to settlers—Austin, DeWitt, DeLeon, and others. After the Texans won their independence and formed a republic, the coastal region became a major artery of commerce and transportation, and it has remained so. During the 150 years that the coastal region has been opened to modern man, increasing changes have occurred. Many changes that result from cultural and technological evolution modify habitation patterns, and alter interactions between man and his natural environment. Indications of these interactions may be found in county records and other documents, on battlegrounds, in graveyards, in architectural forms, along roads, and locally imprinted on the land (where overuse and abuse have been the mode). These are the records of the past, and, whereas the past is a continually expanding arena of time, relics or remnants of days-gone-by are nonrenewable. They are another finite resource, and they are important for cultural, scientific, aesthetic, and psychological reasons. Yet archaeological and historical sites are continually being lost inadvertently by human activities or by natural processes. It is estimated that one-third to one-half of all such recorded sites in this part of Texas have already been so destroyed.*

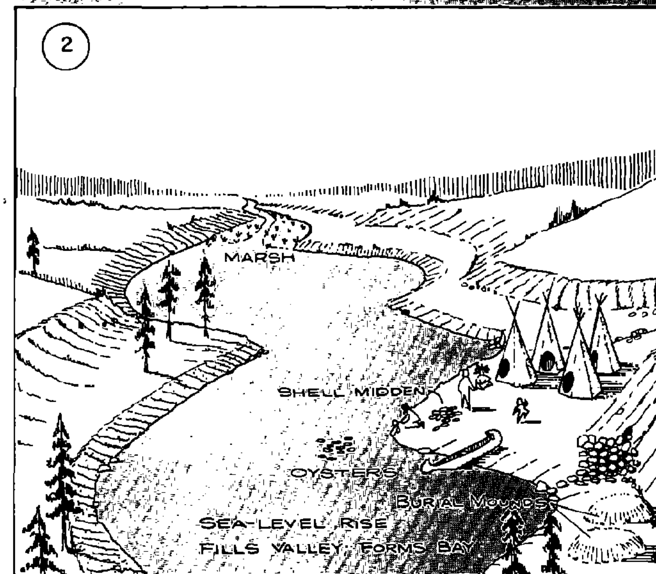
Despite our modern technological "insulation" from natural processes, many lessons can be learned from a study of past interactions between man and nature in the coastal region (fig. 18). Indianola might have been Texas' great port city, but it was destroyed by hurricanes in 1875 and 1886. There is a lesson there and in the Galveston hurricane disaster of 1900. There is a lesson in the surmise that early man caused the extinction of many large mammal species. There are lessons to be learned from man's coping with the drought years of the 1870's, the 1930's, and the early 1950's. There are lessons to be learned from the wanton exploitation during the boom years of gushers and spills and flaring natural gas in the coastal oil fields during the early 1900's. All these lessons show how man exerts impacts on the environment and how the environment exerts impacts on man.

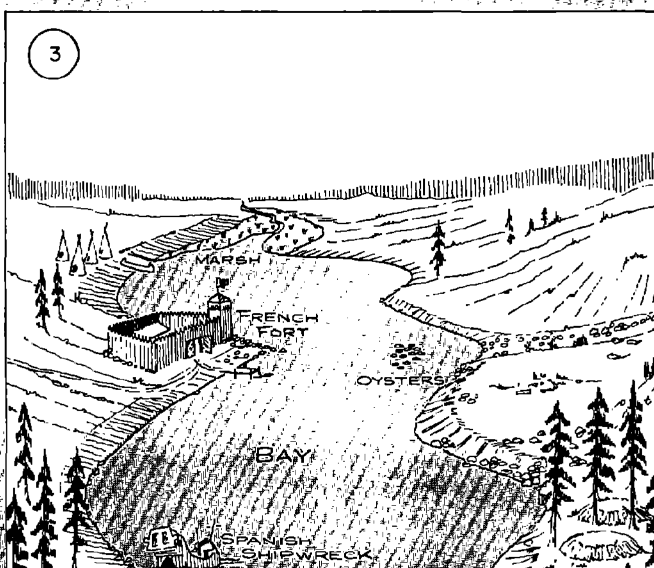
The maps depicting historical and archaeological sites in the coastal region (Pl. 8, A and B) show that less than one percent of the area has been systematically studied. A great data-gap exists anywhere outside these areas of archaeological reconnaissance. The submerged areas of the coastal region are almost totally unexplored. It is difficult to predict where a great new archaeological resource may be found on land or where either a historical site, such as a shipwreck, or an archaeological site may exist on submerged lands. The 27 counties of the coastal region contain 1,859 recorded historical and archaeological sites. This region contains 818 sites having historical markers and 52 sites listed on the National Register of Historic Places.

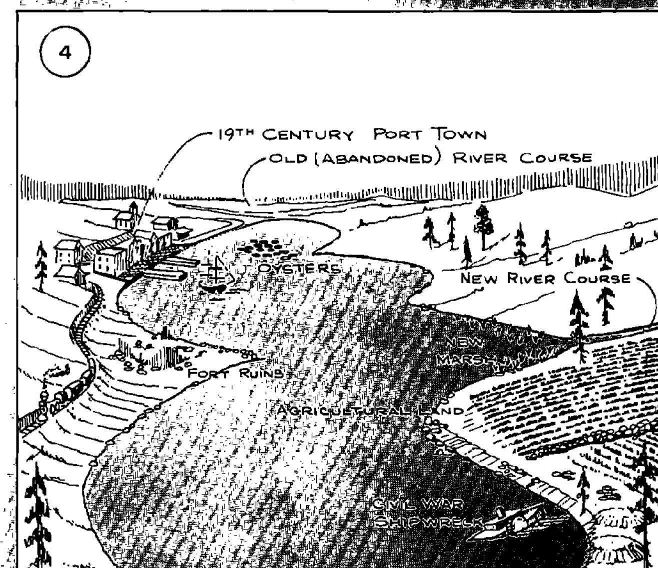
It is in the interest of modern man to learn from the past and to profit from past experiences. Thus, a premium exists on any sites that provide a link with other times and other people and the land.

*All statistics on sites obtained from Warren Lynn of the Texas Historical Commission.









CHANGES IN HUMAN ACTIVITIES IN A HYPOTHETICAL PART OF THE TEXAS COAST

1. PALEO-AMERICAN PERIOD c 10,000 B.C.
2. NEO-AMERICAN PERIOD c. A.D. 1,000
3. COLONIAL PERIOD c 1720
4. NINETEENTH CENTURY c. 1870
5. MODERN PERIOD

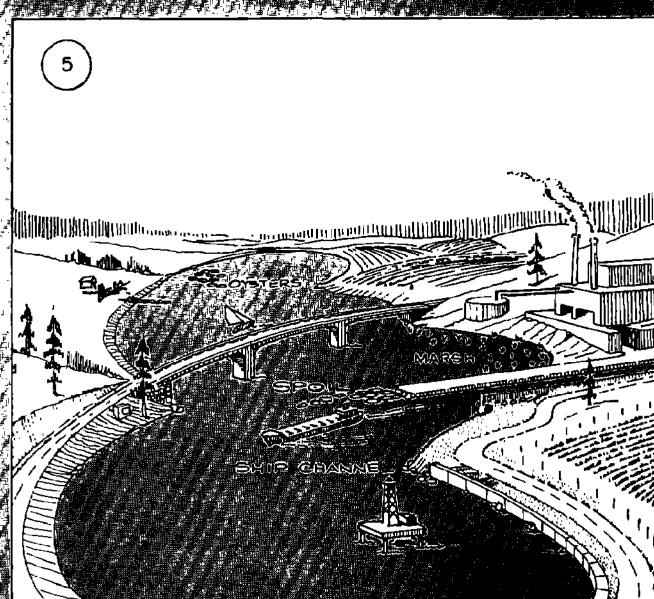


FIGURE 18

THE INVENTORY, PART 9—CURRENT LAND USE

Current land use maps help show man's present use of the land in relation to natural regimes. Current land use maps aid the general public in understanding growth patterns and attendant environmental, economic, or demographic factors. These maps require regular updating.

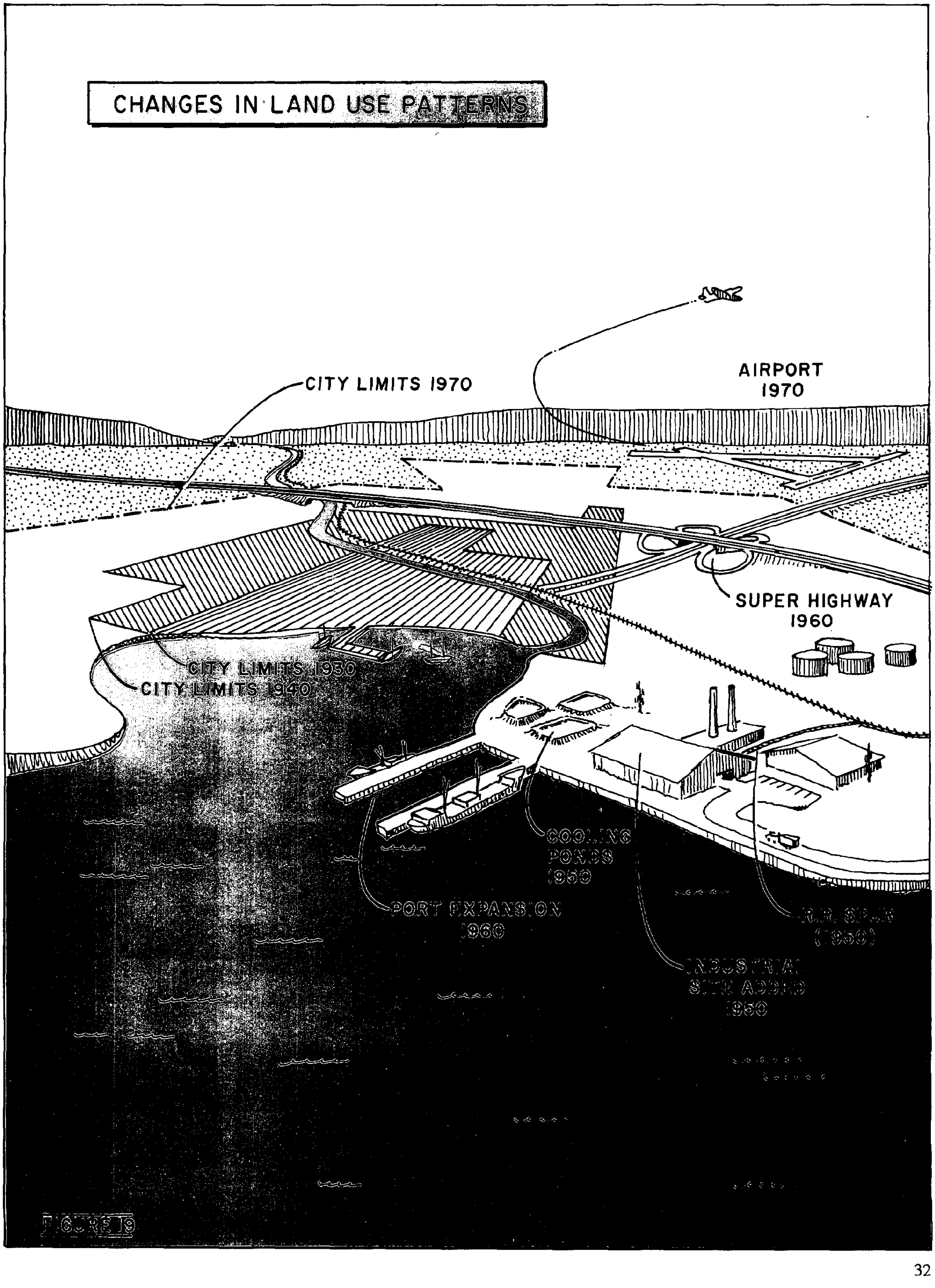
"Current land use" is a representation of the type and extent of human activities in an area at a certain time. Human activities are part of a dynamic cultural system; uses of the land are always subject to change, depending on prevailing economic conditions and depending on the natural capabilities of the land for sustaining uses. For this reason a current land use map is a benchmark from which subsequent changes can be gauged and is a tool for evaluating kinds of uses amenable to specific kinds of land.

Human use of the land imposes a dynamic cultural system onto a dynamic natural base (fig. 19). Man's use shapes the land, and the land shapes many human uses. For example, man changes bay and river regimens when he dredges channels and emplaces spoil. Natural hydrologic characteristics are modified by agricultural practices—replacing natural prairie vegetation with row crops and diverting surface waters via irrigation ditches. The paving of large acreages in urban areas changes the flow conditions of streams. Pumping large quantities of water from certain types of aquifers results in ground surface subsidence. The land, in turn, shapes man's activities in numerous ways. Agriculture is practiced where resources will support it. Mineral extraction occurs only where there are adequate mineral deposits. Cities generally exist where there are ambient water supplies, natural transportation routes, or other factors attractive to settlement. There are many other such examples of interactions between man and the land.

The current land use map is a tool for identifying cultural "pressure points" on the natural systems. It identifies areas of intensive use that may impose imbalances or may activate processes. It identifies the areal limits of other uses that do not "pressure" the carrying capacity of the land. Comparing the current land use display with a map showing natural processes, areas can be shown where man unwittingly exposes himself to natural hazards.

The current land use map of the coastal region (Pl. 9, A and B) is generalized because of its relatively small scale. The dateline of this map combines work done in 1968-1969 with updating based on 1972-1973 Earth Resources Technology Satellite (ERTS) imagery. Because of the regional (small) scale of the ERTS information and because of the 1968 dateline of the base map (from the Bureau of Economic Geology) this map already needs revision in some areas. Updating such a map requires evaluation of the most recent aerial photographic imagery available.

A basic data need in the coastal region and elsewhere in Texas is standardized descriptions of various uses of the land and a coherent classification scheme. Secondly, these uses should be monitored on a large-scale base map (for instance, a standard U.S. Geologic Survey topographic quadrangle map) in order to present a continually revised and updated detailed depiction of current land use. Such monitoring is especially important in the coastal region, where dynamic natural and cultural systems interact and frequently clash.


CHANGES IN LAND USE PATTERNS
CITY LIMITS 1970
AIRPORT 1970
SUPER HIGHWAY 1960
CITY LIMITS 1930
CITY LIMITS 1940
COOLING PONDS 1950
PORT EXPANSION 1960
FIGURE 19

TENTATIVE BOUNDARY FOR COASTAL WATERS

Coastal waters are those waters adjacent to shorelines and containing measurable quantities of sea water. However, their boundaries cannot be mapped in final form, because they change over both short and long periods of time. Boundaries of dynamic natural systems are, by necessity, tentative.

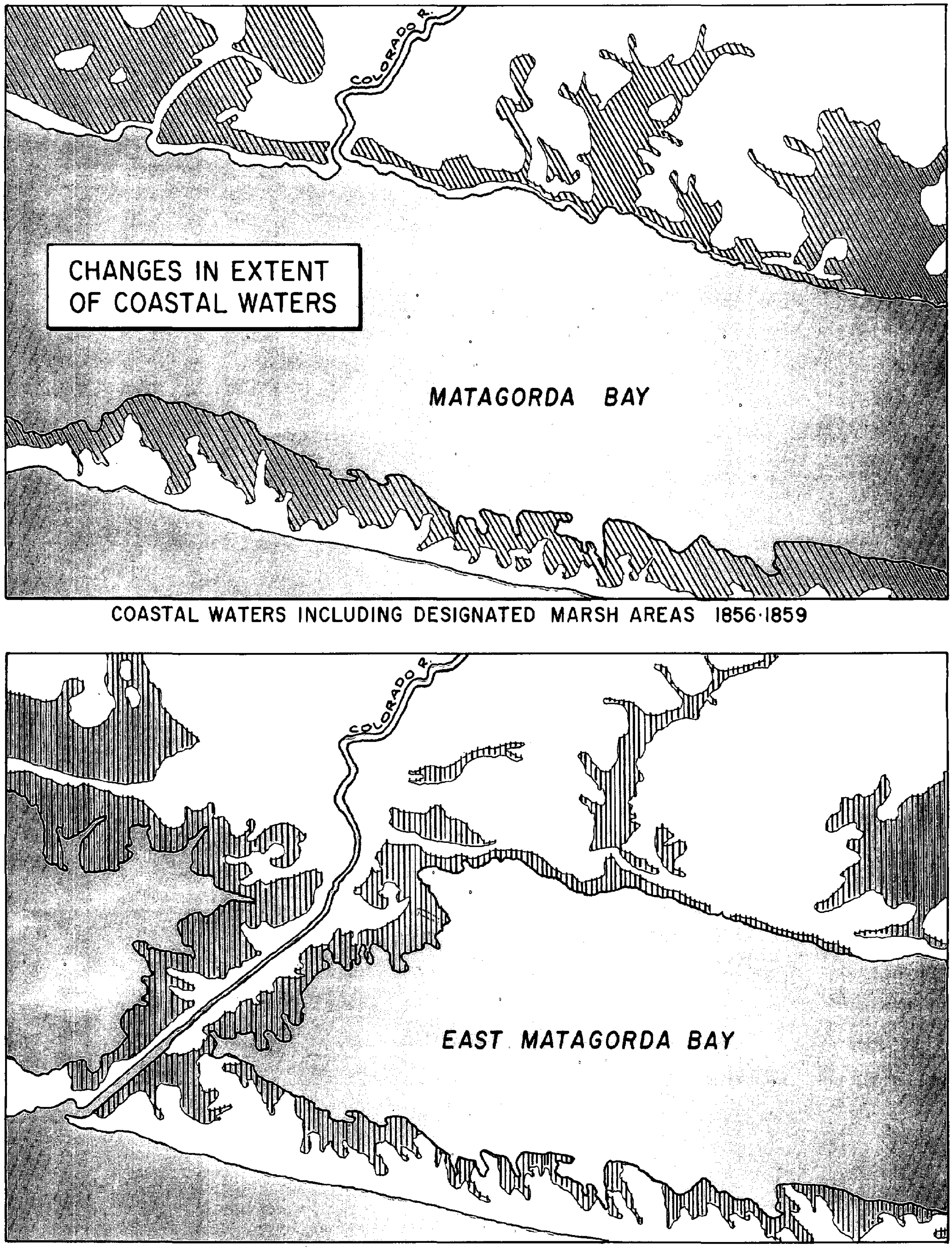
Coastal waters include areas in which a diversity of public interests converge. These waters are important economic assets, supporting commercial fishing, waterborne transportation, recreation and tourism, and mineral production. They also provide natural areas that are significant both ecologically and aesthetically. Finally, the border areas to the coastal waters (wetlands) are important for human safety, for it is here that much of the impact from storms is absorbed. Because of the importance of these waters for sustaining diverse needs, it is logical to consider the coastal waters as a tentative focal point for coastal management. Moreover, federal legislation (Public Law 92-583) encourages the states to establish mechanisms to assure the orderly and productive use of "coastal waters." Indeed, for the purposes of the federal act, the ultimate extent of the Texas coastal region can include only those "shorelands, the uses of which have a direct and significant impact on the coastal waters."

Coastal waters are defined for coastal management purposes as "those waters, adjacent to the shorelines, which contain a measurable quantity or percentage of sea water, including, but not limited to, sounds, bays, lagoons, bayous, ponds, and estuaries." Using this definition as a guideline, a *tentative* boundary for coastal waters may be drawn that includes all stream courses within areas of tidal influences, all salt- to brackish-water marshes, all tidal flats, and all perennial or ephemeral water bodies that lie within or contiguous to these unit boundaries. In addition, "coastal waters" include all areas of open bay and open ocean seaward to the "three-league line," including tidal passes and man-made channels.

This definition is "tentative," because these boundaries cannot be established with certainty as a result of dynamic changes in the various components of coastal waters (fig. 20). Marshes change on a day-to-day basis, and over a long time period, marsh changes may markedly alter boundaries of coastal waters. Likewise, storm surges change (albeit for a short time period) the areal extent of waters containing "a measurable quantity ... of sea water." These changes may be partly natural and partly man-induced; it does not matter which. What is important is that the boundaries of coastal waters are *conceptual* boundaries that are, in fact, parts of dynamic systems. Such boundaries do not lend themselves well to map presentation.

The tentative coastal waters boundary was based on extensive mapping by the Bureau of Economic Geology (BEG) at The University of Texas at Austin. All salient boundaries called for in Public Law 92-583 are proposed. However, 1968 is the general dateline of data collection, and mapping of coastal water boundary changes should be augmented and updated as frequently as possible. This natural (coastal waters) system is fully as dynamic as the cultural systems depicted on the current land use displays. As suggested regarding the updating of changes in cultural systems, it is in the state's interest to continually monitor changes in coastal water systems. This task would entail periodic aerial photographic missions and periodic field work.

Perhaps a static map base is inappropriate for this kind of "monitoring" of dynamic systems. Perhaps digitization of baseline information would offer a partial solution. With such a format, changes could be encoded without the delays and expenses of recurrent cartographic processes. A detailed, valid baseline exists for the Texas coast, based on mapping by the BEG. This is the first step in a necessary ongoing focus on coastal waters.



COASTAL WATERS INCLUDING DESIGNATED MARSH AREAS 1956-1957

FIGURE 20

(After McGowen & Brewton · 1975)

COMPOSITE NATURAL AREAS OF COASTAL WATERS — A TENTATIVE MAP VIEW

Composite natural areas exist within coastal waters as a result of climate, water conditions, substrate, biota, human uses, and other factors, which converge to support or preclude a specific array of natural systems or human activities.

Composite natural areas are mappable entities, either natural or man-made, defined by local characteristics of one or a combination of physical processes, substrate, landforms, soil, biota, or other sustaining factors that naturally support certain described levels of human activities without disrupting the essential set of sustaining characteristics or without imposing hazards on human populations. Composite natural resource areas are similar in concept to resource capability units as mapped by the Bureau of Economic Geology (BEG).

Natural areas on the uplands have been defined herein as a composite of soil assemblages. This differentiation was based on the assumption that soils reflect numerous environmental factors, including climate, substrate, process, terrain, biota, and human influences. The "land types" or "natural areas" based on soils sustain distinct sets of human activities. Prairies and river bottoms generally represent prime lands for cultivation. Poorly drained (saline) areas along the coastal marshlands and barriers are more valuable as wildlife habitats than as agricultural lands. Dissected prairie lands are commonly excellent rangeland but may not be prime cropland. The forested areas in East Texas are typically best suited for forests and serve only locally for range or for cultivation.

Natural areas may also be delineated within submerged and intermittently-submerged areas along the coast; that is, within coastal waters (fig. 21). Criteria such as bathymetry, substrate, local biologic assemblages, and ambient water conditions (salinity ranges, etc.) must be used for the delineation of such areas. Environmental factors converge within certain distinct areas, so that similar sets of natural conditions exist within a set of discrete boundaries. The common boundaries of these environmental factors define the general limits of "composite natural areas."

Composite natural areas exist because of the interdependence of environmental factors. For example, marshlands exist *because* of a delicate equilibrium involving substrate type, bathymetry (or topography), frequency of tidal inundation, freshwater inflow (amount, temporal distribution and chemical quality), and sediment budget. All of these affect floral assemblages (marsh-grasses), which in turn provide a base for the marine food chain. The definition of "composite natural areas" is thus somewhat circular; marshes are defined by component grasses that are one of a number of features "causing" an area to be a marsh. However, for all that, marshlands include a different range of environmental entities and different values of environmental parameters than bays, shoals, fluvial woodlands, or prairies. Marshes can be subdivided into distinct subtypes (saltwater marsh, brackish water marsh, etc.). Also, marshes are part of a dynamic system that changes through time. They represent a composite of natural factors, and they sustain a certain array of conditions; yet they remain distinctly "marshlands." They are thus composite natural areas.

Composite natural areas of coastal waters (Pl. 10, A and B) were compiled based partly on resource capability units (Brown and others, 1971), selected habitat information from the Texas Parks and Wildlife Department, the location of extractable mineral resource areas (from BEG), and the location of certain intensive (or preclusive) human uses of the land.

Composite natural areas of coastal waters include (1) tidal marshlands, (2) coastal lakes and ponds contiguous to tidal marshlands, (3) tidally-influenced reaches of streams, (4) bay regimes, including both open bays—either dominantly river-influenced or dominantly tidally-influenced—and restricted bays locally cut off from significant tidal influence or significant freshwater inflow, (5) tidal flat complexes, including barren land, (6) tidal passes and tidal deltas, (7) areas of submergent grasses, (8) subaqueous (and locally subareal) spoil, (9) various habitats, including living reef complexes, shrimp nursery areas, and waterfowl feeding areas (10) areas of intensive or preclusive human uses (such as ship channels), and (11) areas of significant known mineral resources, such as oil fields underlying submerged areas.

The areas presented herein are tentative, and it may be necessary to refine and further subdivide them after close examination. This testing will involve the demonstration of the various component (sustaining) parameters that constitute each natural area in order to ascertain whether the areas are valid, whether they should be further subdivided, and whether the areas within the same tentative unit reflect similar conditions and constraints coastwide. Testing will also indicate the kind and magnitude of impacts that can be sustained from various human activities. Testing the units in terms of (1) composite environmental factors and (2) the general ability of the units to sustain various impacts will be a major part of the ongoing study by the natural resource section of the Texas Coastal Management Program.

Map units showing composite natural resource areas of coastal waters are tentative also, because of constraints imposed either by map scale, or by continual changes within dynamic systems. Thus, with further refinement either by on-site investigations, or using a more up-to-date data base, variations may be found to exist within and among these units. Still, the need for future refinements does not negate the concept of such natural areas. Instead, these areas provide a focal point for viewing a diversity of resource interactions.

EXAMPLE OF COMPOSITE NATURAL AREA...COASTAL WATERS

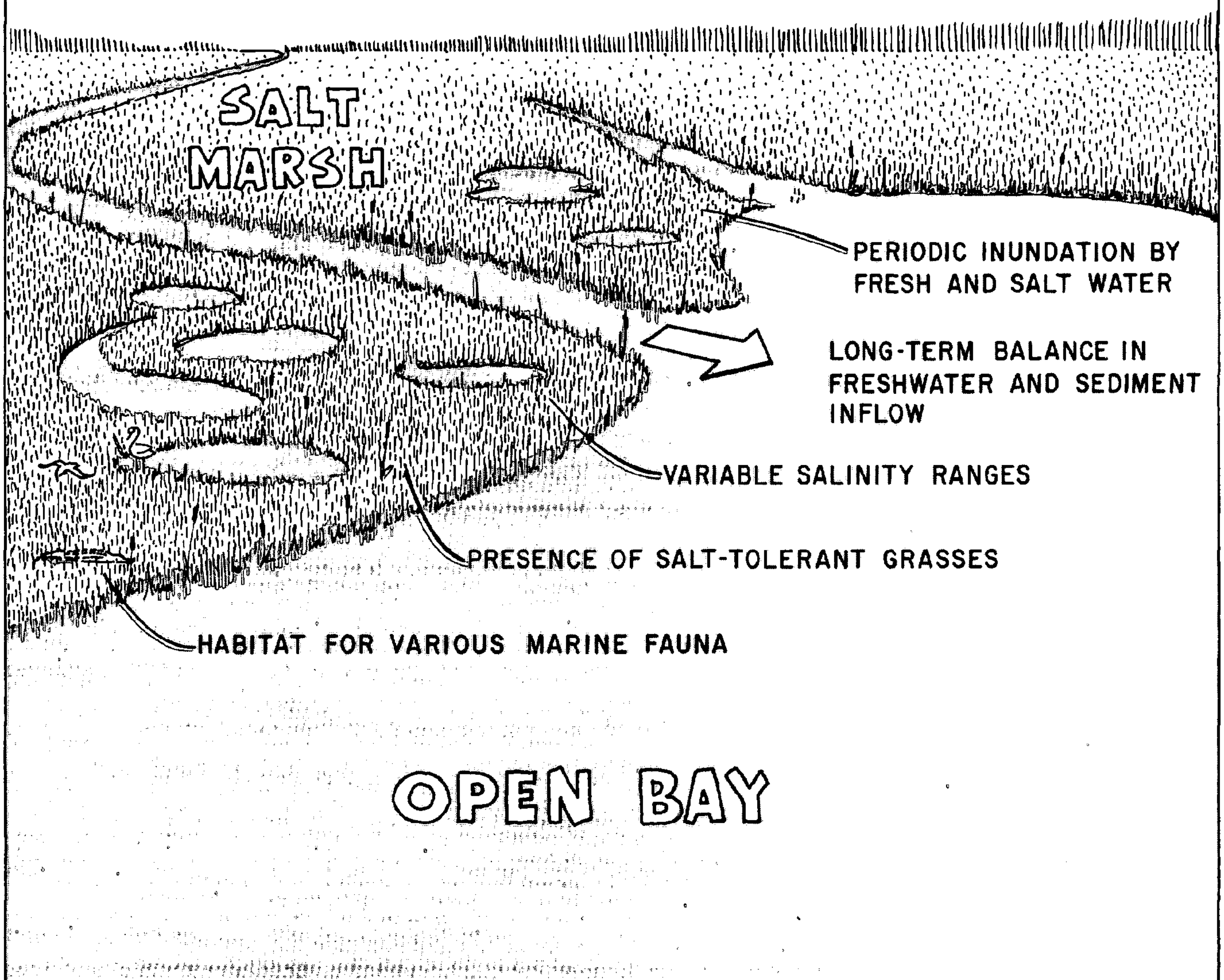


FIGURE 21

NOMINATION OF AREAS OF PARTICULAR CONCERN

Geographic "areas of particular concern" are tentatively defined based on responses from the member agencies of the Texas Interagency Council on Natural Resources and the Environment.

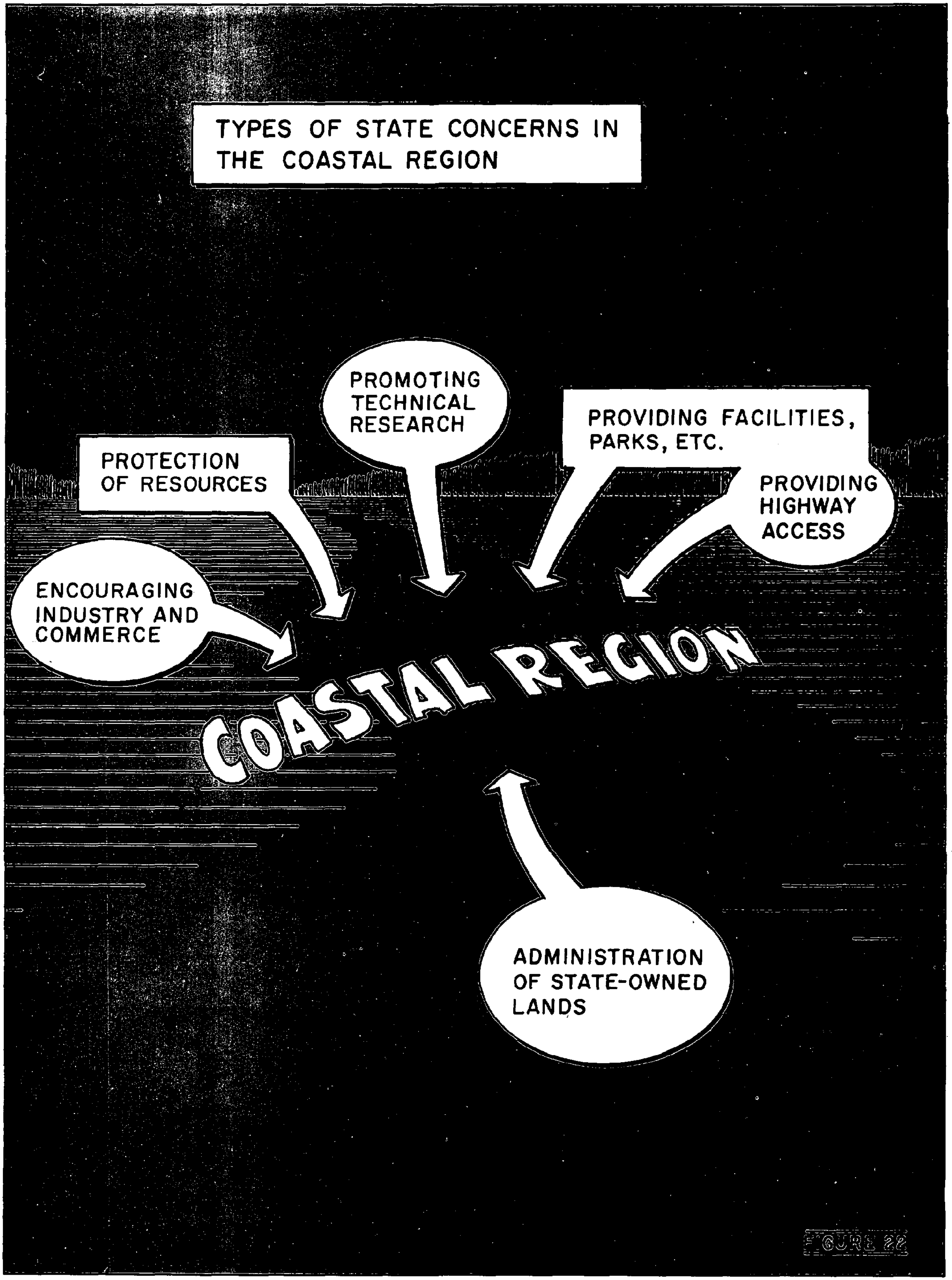
One of the objectives of the Texas Coastal Management Program is to compile and assess problem areas as perceived by various groups. Indeed, Public Law 92-583 encourages this program to include "an inventory and designation of areas of particular concern." The guidelines attendant to the law further expound on this inventory and suggest areas that should be considered. The "areas" referred to are *geographic areas* rather than conceptual ones, and should reflect consideration of:

1. Areas of unique, scarce, fragile, or vulnerable natural habitat, physical feature, historical significance, cultural value and scenic importance;
2. Areas of high natural productivity or essential habitat for living resources, including fish, wildlife, and the various trophic levels in the food web critical to their well-being;
3. Areas of substantial recreational value or opportunity;
4. Areas especially suited to intensive use or development and where developments and facilities are dependent upon the utilization of, or access to, coastal waters;
5. Areas of unique geologic or topographic significance to industrial or commercial development;
6. Areas of urban concentration where shoreline utilization and water uses are highly competitive;
7. Areas of significant hazard if developed, due to storms, slides, floods, erosion, settlement, etc.; and
8. Areas needed to protect, maintain or replenish coastal lands or resources, such areas including coastal flood plains, aquifer recharge areas, sand dunes, coral and other reefs, beaches, offshore sand deposits, and mangrove stands.

It is noteworthy that the law *does not require constraints to be placed upon* "areas of particular concern." Instead, such an inventory is merely a statement of interest and concern. Thus, areas on the uplands—on private land—can be stated as being "of concern," without the slightest imposition upon private property rights. For example, the Texas Department of Agriculture can be "concerned" with arable lands in the private domain, and it may encourage and monitor the state's agricultural productivity as part of its function. This concern in no way infringes upon private property rights. Likewise, other governmental entities can be "concerned" with historic or natural sites that occur on private lands, or with hazardous areas, all without any pretense of interfering with private property.

The method used herein to begin the process of designating these areas has been to solicit nominations of such areas from the members of the Texas Interagency Council on Natural Resources and the Environment (ICNRE) (fig. 22). This council was created by the Governor to act in an advisory capacity and to ensure interagency coordination regarding natural resource matters. The member agencies and institutions also speak for a broad spectrum of interests—those concerned with development, recreation, resource use and conservation, education and preservation. The ICNRE members include the Bureau of Economic Geology, the General Land Office, Texas A&M University, the Texas Air Control Board, the Texas Department of Agriculture, the Texas Forest Service, the Texas Highway Department, the Texas Industrial Commission, the Texas Soil and Water Conservation Board, the Texas Water Development Board, the Texas Water Rights Commission, the Texas Water Quality Board, The University of Texas, the Texas Parks and Wildlife Department, the Texas Railroad Commission, and the Texas Historical Commission.

The polling of this public group seemed an effective means to begin the designation of these areas. It would be presumptuous for only the staff of this program to enumerate "areas of particular concern" for such broad subjects as stated in the federal guidelines. Yet, a process of "consultation" could become unwieldy if opened to the complete forum of federal, regional, and local governing bodies, special interests, and the public at large. All groups should eventually be able to contribute to the determination of these areas, but a first approximation developed by the Texas Coastal Management Program will be used to initiate the process. Thus, the designation of areas of particular concern is tentative. It is subject to extensive review and modification by governmental entities at all levels and by the general public. Some areas may be added, or others deleted as the program progresses.


TYPES OF STATE CONCERNS IN THE COASTAL REGION
PROMOTING TECHNICAL RESEARCH
PROVIDING FACILITIES, PARKS, ETC.
PROTECTION OF RESOURCES
PROVIDING HIGHWAY ACCESS
ENCOURAGING INDUSTRY AND COMMERCE
COASTAL REGION
ADMINISTRATION OF STATE-OWNED LANDS
FIGURE 22

AREAS OF PARTICULAR CONCERN — A TENTATIVE MAP VIEW

Areas of particular concern nominated by ICNRE entities are presented on a common base map. This map demonstrates the complexity of such "nominated areas" by showing (1) overlap (and conflicts) of areas named by different entities for different reasons, and (2) inclusion of broad and sometimes vague areas of concern that cover the entire coastal region.

A map showing the composite of "areas of particular concern" nominated by ICNRE agencies shows an exceedingly complex array (Pl. 11, A and B). The complexity is partly a result of the breadth of definition of "concern" among various entities. Complex boundaries and interactions (i.e., multiagency overlap) among the nominated areas are also the result of imprecise limits of cultural and natural systems.

Areas of particular concern for each ICNRE entity reflect one or a combination of (1) statutory mandates for control, regulation, or monitoring; (2) areas of focus for research endeavors; (3) areas for which the public entity is an advocate; and (4) other areas perceived to be important or ancillary to the performance of agency duties.

Some nominations are map-specific, and some are textual. Area designations are based on the loci of natural resources, on the areal extent of cultural resources, and on the extent of hazardous areas. The multiplicity of criteria for nomination of critical areas ensures that most of the region will be blanketed by one or more concerns. This is partly because of diverse interpretations of "criticality" and partly because of the complexity of natural and cultural systems. Areas of concern include most lands within the 27 component counties of the coastal region as well as offshore areas to the three-league line. There are also some areas where multiple designation of areas of concern occurs because of overlap in interests. Some agencies state concerns based on interests in preservation and restoration. Some express concern because of a purely academic focus, and some agencies state concern because of interest in development of resources.

Blanket or region-wide designations of areas of concern commonly reflect the breadth of statutory mandates or research interests of agencies or institutions. For example, the totality of coastal waters may be designated "of concern" by an academic entity, because of multiple research interests within the waters, transitional areas, and submerged lands. Likewise, certain agencies may be concerned with the loci of recharge for the important Gulf Coast aquifer, even though a precise limit cannot be drawn on the recharge zone. Therefore, pending further study to clarify the exact limits of recharge, the entire uplands may be of concern, insofar as groundwater recharge occurs directly within this terrain, or insofar as waters are collected and transported via natural channels into loci of recharge. Other agencies may designate most of the uplands as an area of concern in order to be apprised of new historical or archaeological discoveries throughout the region. Still other agencies may be concerned with all the uplands as habitat for game and fowl, because the state owns the *wildlife*, even though it does not own the land on which the wildlife lives. Thus, to grasp the proper significance of the nominations presented herein, one must consider carefully the substance of the avowed "concern" as well as its areal extent.

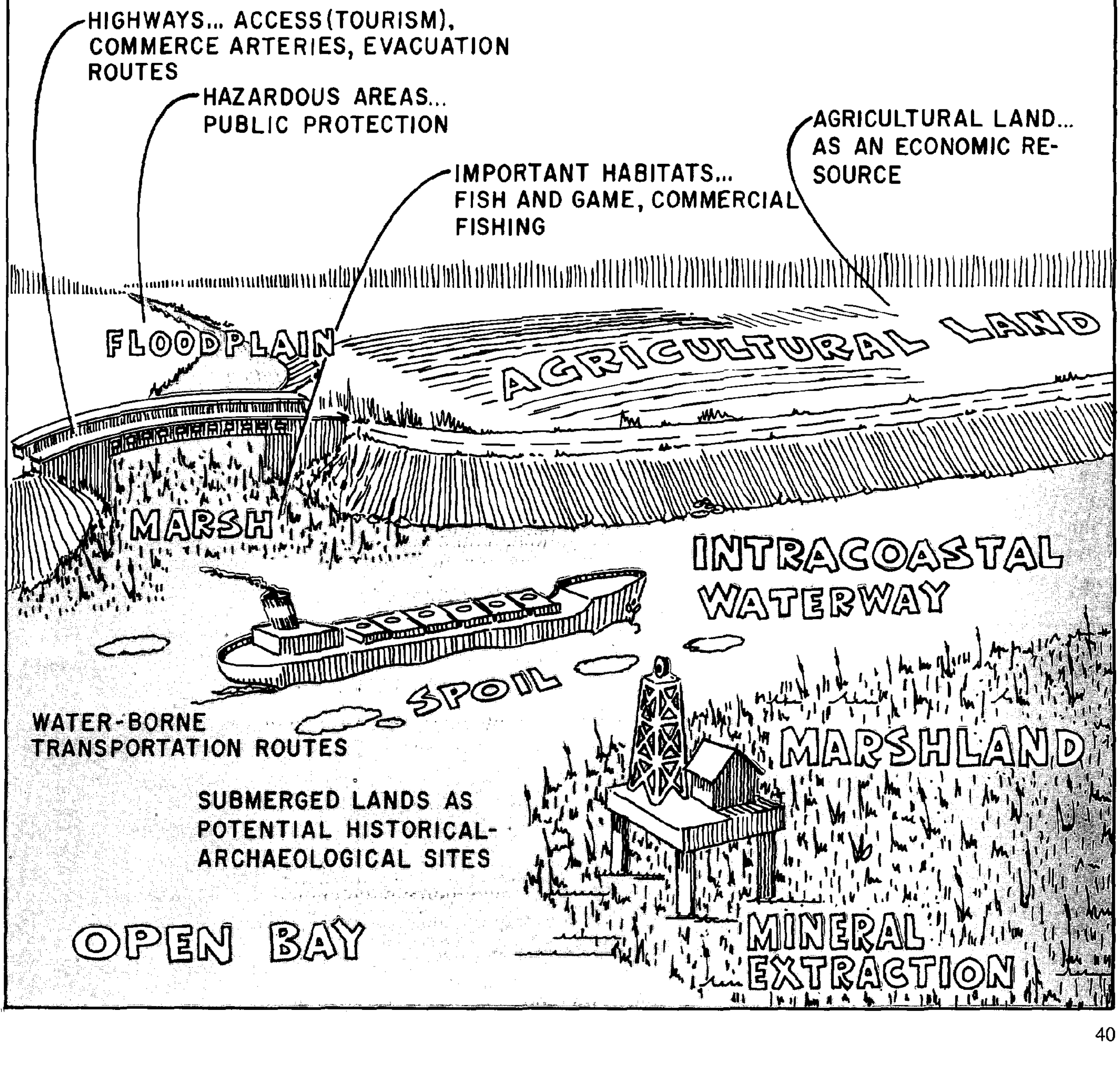
Examples of multiple overlap among agency nominations include tidal marshlands. These have been designated and mapped by the Bureau of Economic Geology as an important area for sustaining coastal biota, as well as a buffer zone for lessening impacts of coastal processes (i.e., the marshlands are subject to periodic inundation). The same areas are designated as being of concern to the Texas Parks and Wildlife Department because they constitute important habitats for waterfowl and selected marine biota. Also, these same areas may be part of locally designated natural preserves or wildlife sanctuaries. Marshlands are also designated by the Texas Industrial Commission as areas critical to sustaining the private commercial fishing industry in Texas as well as a tourist industry based in part on game and sports fishing.

Submerged lands are designated by the Texas Historical Commission as potential historical or archaeological sites. Locally, the same areas might be designated by the Railroad Commission because of oilfields beneath the coastal marshes, or by the Texas Industrial Commission as areas needed for channel dredging and spoil disposal.

These region-wide boundaries and areas of overlap (regarding what is perceived to be "of concern" by different entities) are all tentative. They are merely a first approximation and will be revised and updated as a continuing part of this planning effort. A very important part of this process will be comments submitted by concerned citizens and the various interest groups.

FIGURE 23

SELECTED AREAS OF CONCERN NOMINATED BY STATE AGENCIES



CONCLUSIONS

An overview of resources of the Texas coastal region reveals several basic points:

1. Coastal resources are complex and interdependent.
2. Part of the complexity of natural and human systems stems from their dynamic interactions.
3. Composite areas exist on land and in water; these areas reflect the dynamic and complex overlap of natural and human systems.

In assessing the resource base of the coastal region, an inventory was conducted based on currently available data. This inventory covers physiography and climate, substrate, water resources, physical processess, soils, biologic resources, minerals, and historical-archaeological sites and current land use.

The inventory is presented on a suite of maps depicting each component resource. The map format is an effective means of arraying diverse systems for comparison, and it allows a more complete understanding of the interdependence among different kinds of resources. This interdependence is evident in the similar geographic extent of diverse map features. For example, similar map patterns may be seen in certain areas for substrate, soils, and biota. This similarity occurs because soils are derived from substrate, and upland biota generally depend on soils. However, there are certain problems with map presentations. Detail is commonly lost because of the necessary use of maps at a regional scale. Also, maps are static documents; they cannot adequately portray systems that change rapidly.

In demonstrating the convergence of diverse natural systems, maps allow one to tentatively delineate natural areas for both uplands and coastal waters. These natural areas are defined by specific suites of environmental characteristics that render each area distinct, notwithstanding interactions across natural area boundaries. For example, upland natural areas may be defined by a grouping of similar soil types, because soils reflect a diversity of factors—climate, biota, substrate, water conditions, and time. For coastal waters, the designation must especially allow for dynamic interplay among components, because of the constant changes in flows of water, inorganic and organic materials, and migrations of living organisms. The constantly changing conditions are largely a result of seasonal or climatic factors with attendant variations in freshwater inflows, tidal ranges, biologic responses, and erosional or depositional processes. These dynamic water systems are extremely complex. Thus, they are difficult to properly present and evaluate on a map base.

Natural interactions in coastal waters also affect numerous important human activities. Likewise, human uses of the lands and waters commonly affect natural coastal water regimes. Human activities that may impact or be impacted by coastal waters include shipping, commercial fishing, mineral resource extraction, and recreation, yet no one activity has a clear and overriding franchise to these waters. Coastal waters represent a locus of present and potential conflicts, yet these waters respond to a complex set of conditions that are only vaguely predictable. Because the convergence of human demands is coupled with a lack of understanding regarding all the interfacing components of coastal waters, these waters are the immediate concern of the Texas Coastal Management Program.

Focusing upon coastal waters involves several tasks. The coastal waters must be tentatively defined. Component natural areas should be designated and tested as to their validity. Finally, examinations should be made regarding sustaining or constraining conditions (either natural or man-induced) pertinent to each natural area. To date, the first tasks have been accomplished. Tentative boundaries have been set for coastal waters, and preliminary natural areas have been designated. The evaluation and testing of these designations must await further study.

Natural resource areas of coastal waters include various bay and estuarine systems, tidal marshlands and other wetlands, areas of submerged grasses, reefs, tidal passes, and fish and fowl habitats. In addition, selected important man-influenced features are incorporated into the natural area definitions. These include channels, waterways, selected dredged-material disposal areas, and locations of offshore oil production. The final limits of coastal waters and component natural areas will be subject to review and modification.

Texas state agencies, in addition to providing a wealth of information pertinent to the inventory, have stated the geographic extent of their respective concerns regarding coastal (region-wide) resources. Some of these areas of concern are precisely-defined localities, whereas others are, by necessity, generalized. They reflect regulatory mandates, academic interests, concern for the safety of inhabitants, concern for continued economic development, and concern for the preservation of selected areas deemed important. These nominated areas of particular concern will be submitted for public review, as they are merely a first approximation of the state's attempt to articulate its interests in coastal resources.

It is important for the people of Texas to be apprised of the diverse array of natural resources and physical processes that converge in the coastal region. It is also important for areas of concern, as perceived by different groups, to be clearly stated. This allows a more complete understanding of the resource base and the potentially conflicting interests that vie for these resources. Information regarding what the resources are will contribute to this common understanding of salient resource issues and a more rational resolution of conflicts.

SCHEMATIC INTERACTIONS AMONG DIVERSE NATURAL AND HUMAN SYSTEMS

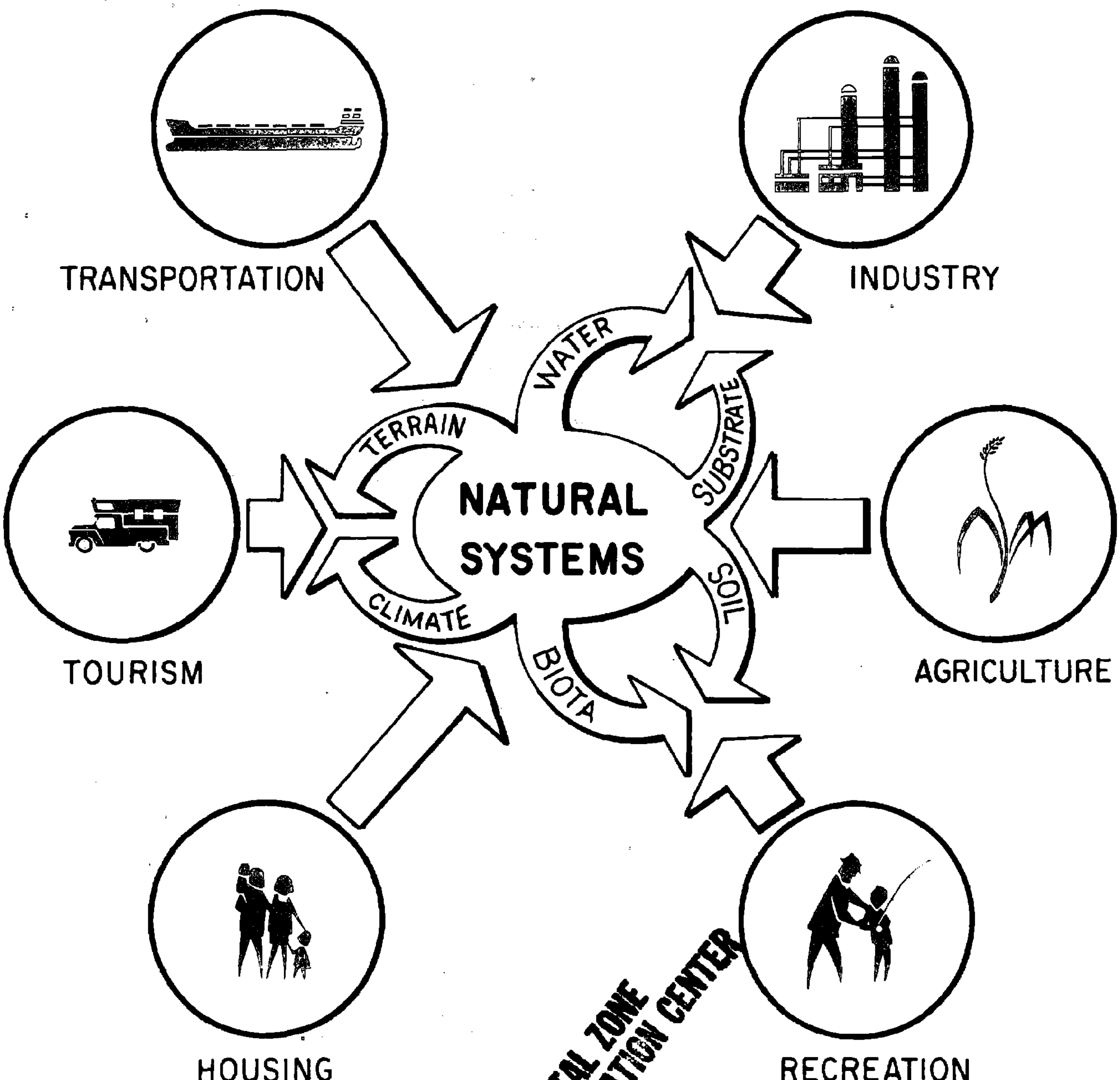


FIGURE 24

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